This page is a reference page used to track documents internally for the Division of Oil, Gas and Mining

Mine Permit Number M0450017 Mine Name Mercur Mine
Operator BARRICK Resources Date April 26 1982
TO ______ FROM ______

__CONFIDENTIAL __BOND CLOSURE __LARGE MAPS X EXPANDABLE
__MULTIPUL DOCUMENT TRACKING SHEET __NEW APPROVED NOI
__AMENDMENT _OTHER ______

Description YEAR-Record Number

__NOI X Incoming __Outgoing __Internal __Superceded

Application for Permint construct
Reservation CAnyon TAiling site

__NOI __Incoming __Outgoing __Internal __Superceded

__NOI __Incoming __Outgoing __Internal __Superceded

__NOI __Incoming __Outgoing __Internal __Superceded

__TEXT/ 81/2 X 11 MAP PAGES __11 X 17 MAPS __LARGE MAP

COMMENTS: ______

CC: ______

4/26/1982

M/045/017

Application for Permit to Construct
Reservation Canyon Tailings Site

Getty Mining Company

Made to
Bureau of Water Pollution Control

REPORT ON

TAILINGS DAM AND POND

RESERVATION CANYON

MERCUR GOLD PROJECT

TOOELE COUNTY, UTAH

Prepared for:

GETTY MINING COMPANY

SALT LAKE CITY, UTAH

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

		Page No.
1.0	Introduction	1
1.1	Summary	1
1.2	Site Location and Description	12
2.0	Design Criteria	14
2.1	Scope	14
2.2	Design Life	14
2.3	Regulatory Requirements	14
2.4	Hydrology	15
2.5	Embankment Design Criteria	16
2.5.1	Embankment Construction	16
2.5.2	Embankment Freeboard	16
2.5.3	Embankment Settlement	17
2.5.4	Impervious Core Thickness	17
3.0	Geology	18
3.1	Regional Geology	18
3.2	Stratigraphy	18
3.3	Structure	20
3.4	Local Geology	21

TABLE OF CONTENTS (Cont'd)

SECTION		Page No.
3.4.1	Local Faulting	24
4.0	Seismicity and Faulting	25
4.1	Active Faults and Seismic History	25
4.2	Design Earthquakes	31
5.0	Field Investigations	31
6.0	Laboratory Investigations	35
7.0	Hydrology	45
7.1	General	45
7.2	Surface Water	45
7.3	Ground Water	46
7.4	Hydrologic Design of Tailings Impoundment	62
7.5	Runoff Volume	63
8.0	Seepage	67
8.1	Tailings Pond Construction and Operation	67
8.11	Dam Construction	67
8.12	Tailings Disposal	68
8.2	Tailings Distribution Model	76
8.2.1	Introduction	76
8.2.2	Tailings Disposal Model	79
8.2.3	Wetted and Underwater Beach Profiles	83

TABLE OF CONTENTS (Cont'd)

SECTION		Page No.
8.2.3.1	Wetted Beach	83
8.2.3.2	Underwater Beach	84
8.2.4	Results of Calculation	86
8.3	Seepage Model	87
8.3.1	Subsurface Material	90
8.3.2	Modeling Approach	92
8.3.3	Results of Analysis	92
8.3.4	Limitations	101
8.4	Water Balance	102
8.5	Initial Tailings Liquor Chemistry	106
8.6	Elements of Interest	107
8.7	Existing Environmental Conditions	107
8.8	Cyanide Degradation	109
8.8.1	Cyanide Waste Degradation	111
8.8.2	Alkaline Chlorination	116
8.8.3	Ozonation	117
8.8.4	Other Treatments	118
8.8.5	Natural Degradation of Cyanide	119
8.8.6	Acidification/Volatilization	119
8.8.7	Oxidation	121
8.8.8	Biodegradation	121
8.8.9	Photodecomposition	122
8.8.10	Conclusion	122

TABLE OF CONTENTS (Cont'd)

SECTION		Page No.
8.9	Contaminant Migration	124
8.9.1	Dispersion	125
8.9.2	Adsorption	127
8.9.3	Precipitation	128
8.9.4	Summary of Attenuation Effects	132
8.10	Summary of Impacts	133
8.11	Mitigation Measures	134
8.12	Monitoring Wells	135
8.13	Reclamation	136
9.0	Conclusions	137
LIST OF REFERENCES		138-140

LIST OF FIGURES

Figure Number		Page No.
1.1	Tailings Disposal Dam Location Map	2
1.2	Tailings DisposaL Dam Plan of Site Drainage Area	3
1.3	Tailings Disposal Dams Cross-section	5
1.4	Tailings Disposal Dam Plan First Stage 2 years	6
1.5	Tailings Disposal Dam Plan Second Stage 6 years	7
1.6	Tailings Disposal Dam Plan Third Stage 12 years	8
1.7	Tailings Disposal Dam Longitudinal Section	10
3.1	General Surficial Geology Rush Valley and Mercur	19
3.2	Preliminary Geological Map - Mercur Gold Project	22
4.1	Earthquake Epicenters	26
5.1	Tailings Disposal Dam Subsurface Investigation	32
5.2	Tailings Disposal Dam Subsurface Profile	33
7.1	Regional Hydrologic Features	48
8.1	Tailings Disposal Dam Filter Drain Details	69
8.2	Tailings Disposal Dam - 2 year Borrow Pit	70

LIST OF FIGURES (cont'd)

Figure Number		Page No.
8.3	Tailings Disposal Dam - 6 Year Borrow Pit	71
8.4	Tailings Disposal Dam - 12 Year Borrow Pit	72
8.5	Tailings Disposal Scheme - Plans and Detail Sheet 1	73
8.6	Tailings Disposal Scheme - Plans and Detail Sheet 2	74
8.7	Tailings Disposal Scheme - Plans and Detail Sheet 3	75
8.8	Interface Settling Velocities in Laboratory Test	77
8.9	Development of Beach on Tailings Pond	80
8.10	Distribution of Solid Concentrations in Tailings Disposal	82
8.11	Beach Profiles	85
8.12	Tailings Deposition Rate at Different Elevations	89
8.13	Flow Pattern in Seepage Model	91
8.14	Extent of Contaminant Plumes at the End of 12 years	96
8.15	Seepage Rate vs Time	97
8.16	Seepage Rate vs Surface Area of Pond	98
8.17	Water Balance First Year	105
8.18	Relative Amounts of Hydrocyanic Acid and Cyanide Ion in Solution as a Function of pH.	120

LIST OF TABLES

Table Number		Page No.
4.1	Check List of Earthquakes	27-28
6.1	Analysis From Composite Sample Treated by Direct Carbon-in-Leach	36-37
6.2	Gradation Test Results	38
6.3	Specific Gravity Test Results	39
6.4	Atterberg Limits Test Results	39
6.5	Laboratory Permeability Test Results	40
6.6	Clay Mineralogy Test Results	41
6.7	Soil Geochmeical Test Results	42
6.8	Buffering Capability Test Results	43-44
7.1	Well Inventory	50-56
7.2	Record of Selected Springs	57-60
7.3	Inflow Volumes for Storms of Different Recurrence Intervals	65
7.4	Freeboard Requirementss	66
7.5	Inflow Volumes for Different 24-hour Storms	66
8.1	Screen Analysis of Mercur Tailings	78
8.2	Model Inpout Parameters	93

LIST OF TABLES (cont'd)

Table Number		Page No.
8.3	Thickness of Tailings vs Time Step	94
8.4	Seepage Characteristics at the End of 12 years	99
8.5	Water Balance - Reservation Canyon Tailings Pond	103-104
8.6	EPA and Utah Water Quality Standards	108
8.7	Common Metal Cyanide Complexes and Compounds	113
8.8	Same Metal-Cyanides Complex Ions in Order of Decreasing Stability in Water	114
8.9	Free Cyanide Concentration Released at Various Levels of Total Cyanide	115
8.10	Estimated Capabilities of Processes to Remove Cyanide/Metal from Gold Mine Effluents	123
8.11	Golden Gate Tailings Drill Hole Chemistry	130
8.12	Selected Water Chemistry Mercur Area	131

1.0 INTRODUCTION

1.1 Summary

This report documents the geotechnical design of a 270 foot high embankment to retain tailings at Reservation Canyon. It covers the site's geological and seismicity studies, subsurface and laboratory investigation, embankment design criteria, and site hydrology. This dam is located within 4000 feet NE of the old town of Mercur, Tooele County, Utah, within the Mercur Gold Project Area. See Figures 1.1 and 1.2.

The design life of the Pond is 12 years. One million cubic yards of tailings will be deposited during the first year, and 0.8 million per year during the remaining 11 years. The total impoundment volume will be 9.8 million cubic yards. The embankment shall be constructed in stages to minimize initial capital investment. Its final height shall be 270 feet. The Stage I embankment will store two years worth of tailings operation. Stage II will hold a total capacity of 5.8 million cubic yards. Stage III completes the storage capacity to a total of 9.8 million cubic yards.

Topographical characteristics dictate the need for constructing a saddle dam on the south side of the tailings pond. Foundation materials for the main dam consist primarily of a colluvium deposit of silty sand and limestone fragments

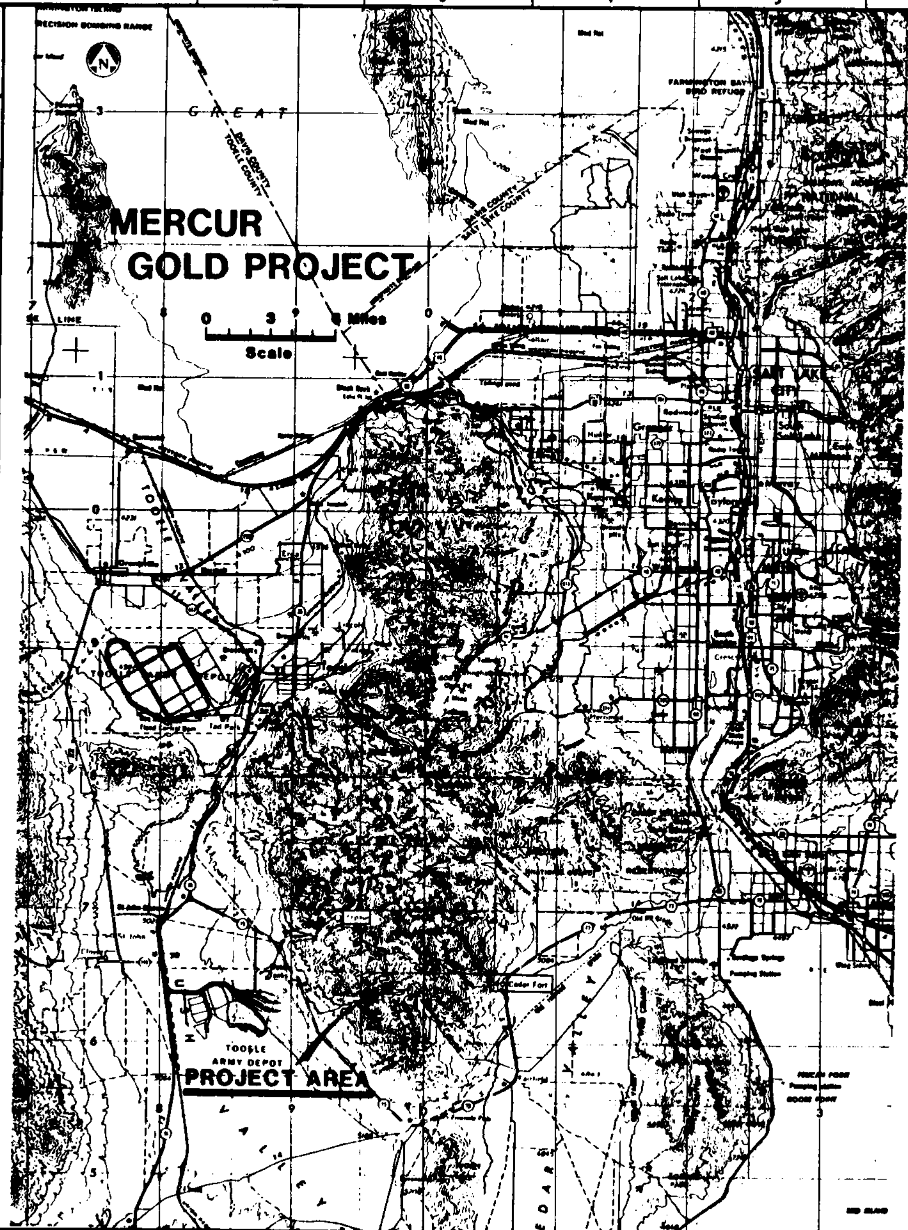


FIGURE 1.1

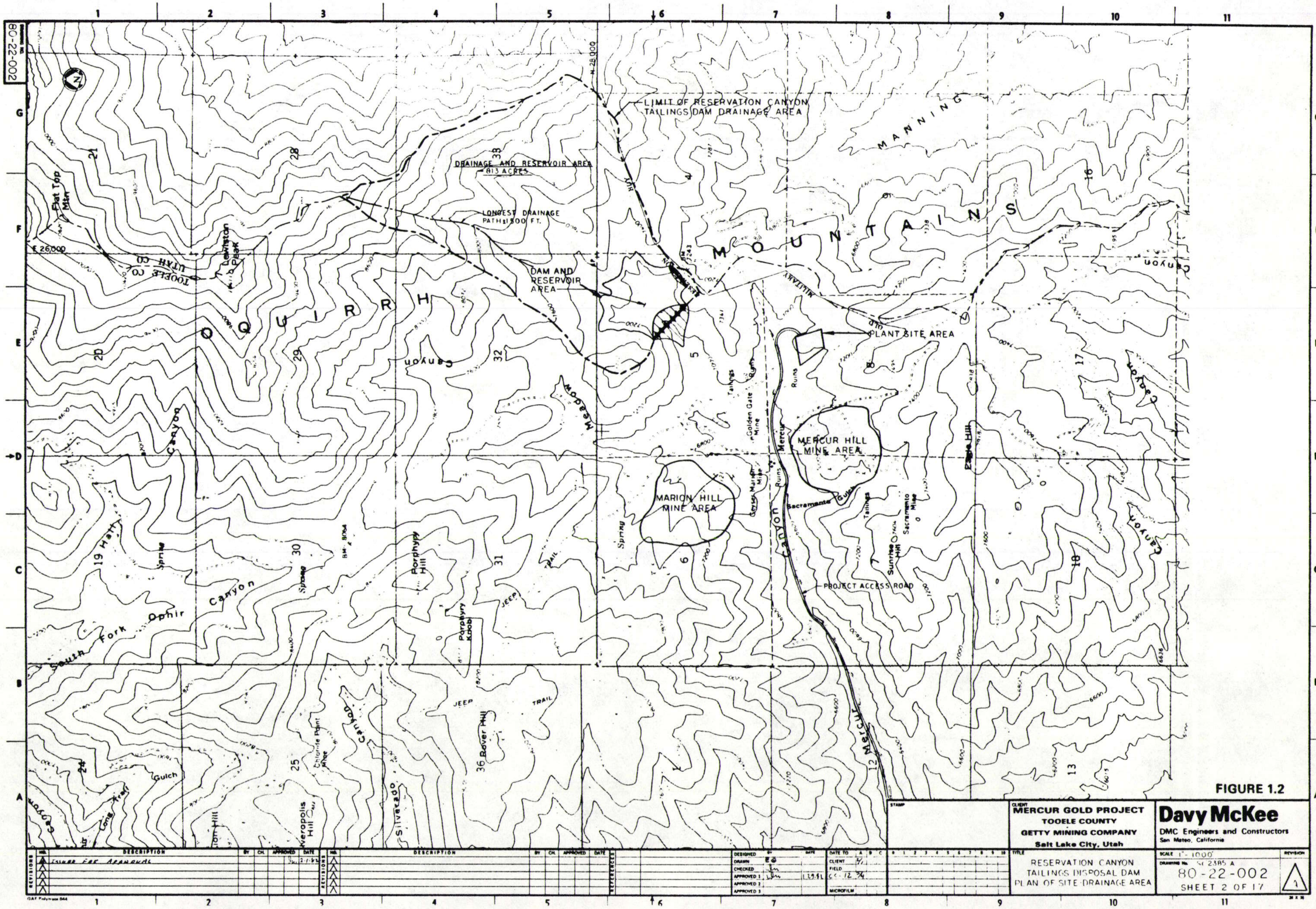
MERCUR GOLD PROJECT
TOOELE COUNTY
GETTY MINING COMPANY
Salt Lake City, Utah

Davy McKee
DMC Engineers and Constructors
San Mateo, California

RESERVATION CANYON
TAILINGS DISPOSAL DAM
LOCATION MAP

SC2385 A
80-22-001
SHEET 1 OF 17

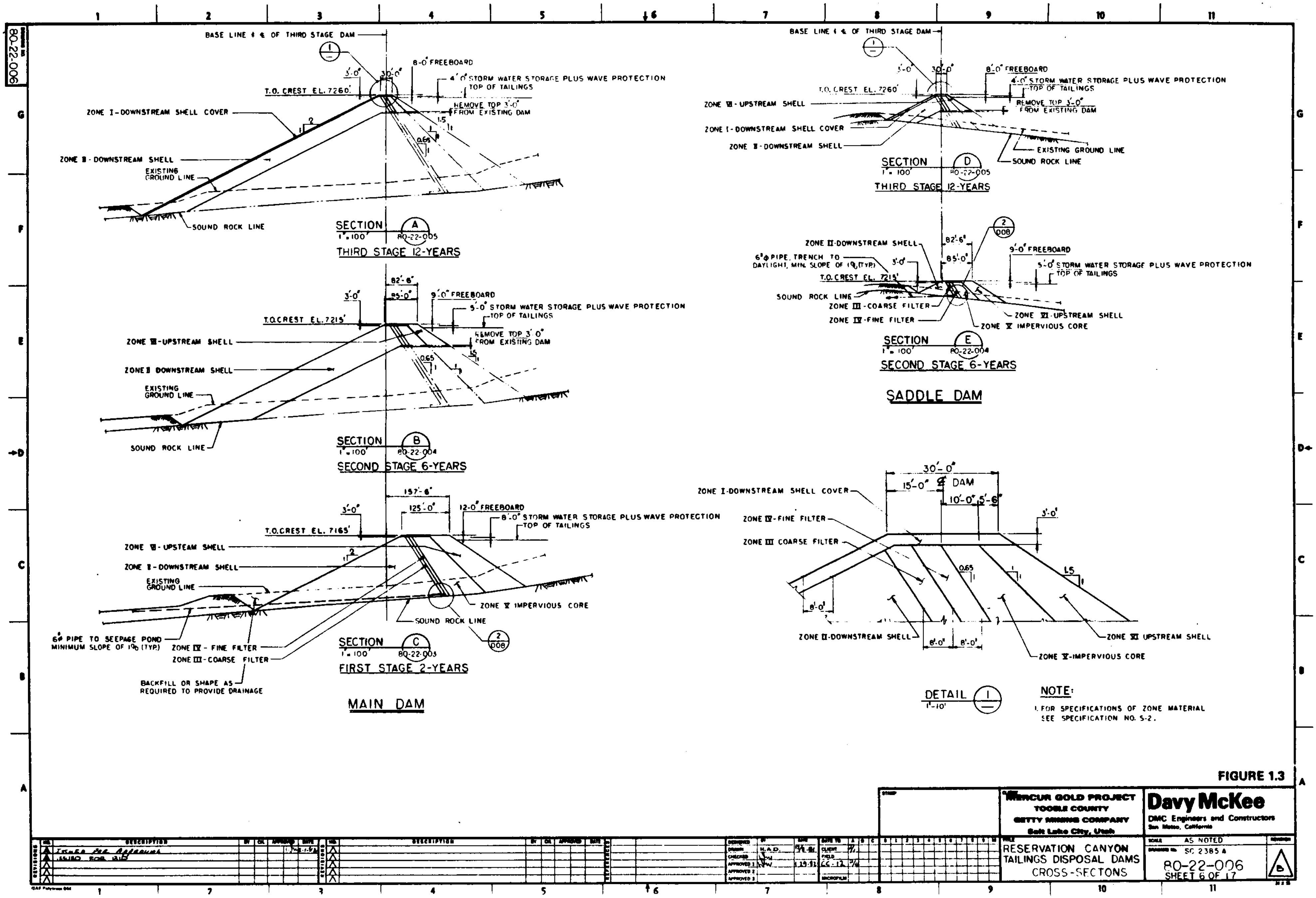
80-22-001

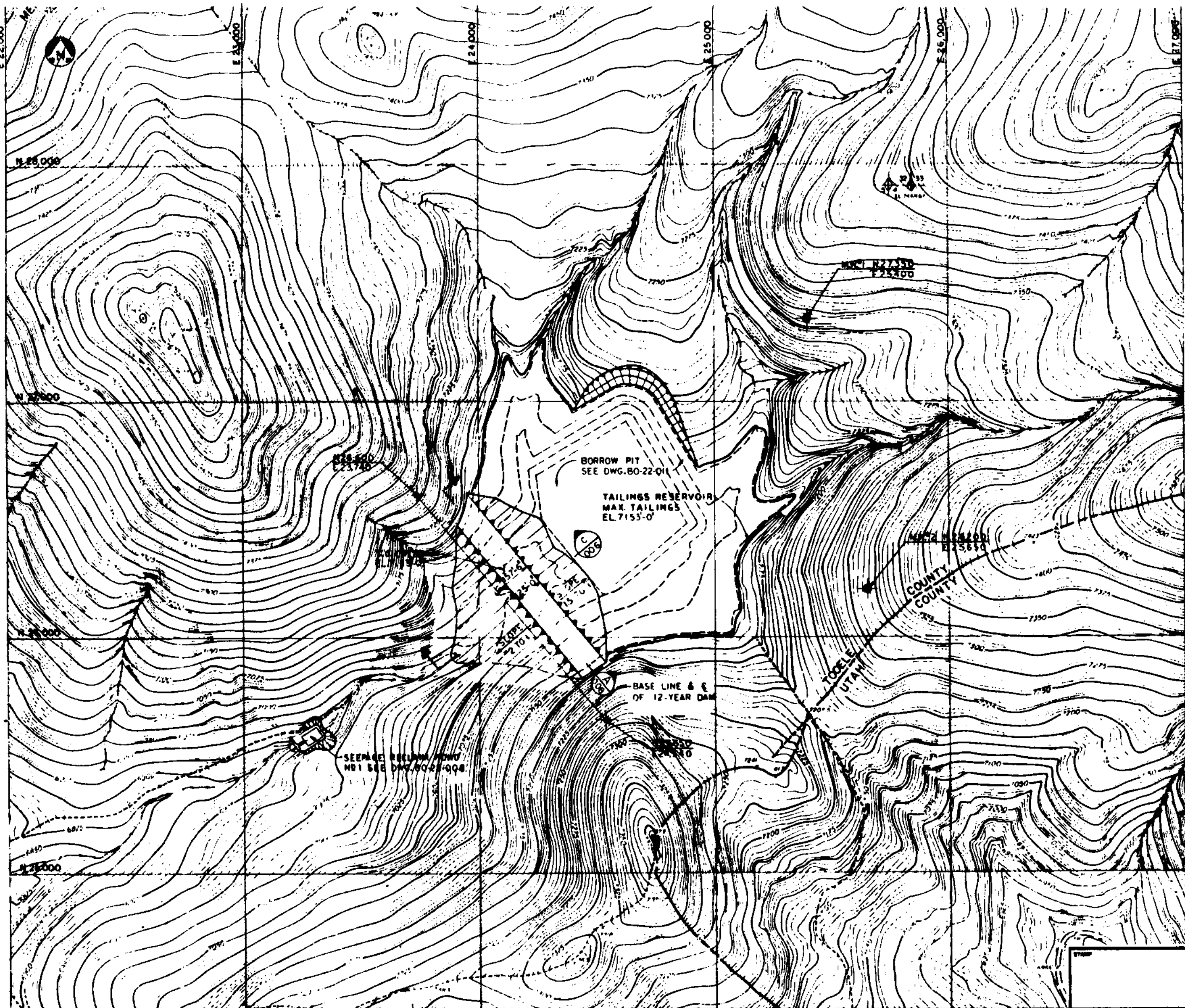

LIMIT OF RESERVATION CANYON
TAILINGS DAM DRAINAGE AREA
DRAINAGE AND RESERVOIR AREA
813 ACRES
LONGEST DRAINAGE
PATH±1500 FT.
DAM AND
RESERVOIR
AREA
PLANT SITE AREA
MERCUR HILL
MINE AREA
MARION HILL
MINE AREA
PROJECT ACCESS ROAD
OQUIRRH
MOUNTAINS
MANNING
TOOELE CO
UTAH CO
Lewiston Peak
Flat Top Mtn
Porphyry Hill
Porphyry Knob
Rover Hill
Sunrise Hill
Sacramento Mine
Golden Gate Mine
Meadow
Canyon
Mercur
Ophir
South Fork
Silverado
Gulch
JEEP
TRAIL
Spring
Tailings
Ruins
MILITARY
HWY
FIGURE 1.2
MERCUR GOLD PROJECT
TOOELE COUNTY
GETTY MINING COMPANY
Salt Lake City, Utah
Davy McKee
DMC Engineers and Constructors
San Mateo, California
RESERVATION CANYON
TAILINGS DISPOSAL DAM
PLAN OF SITE DRAINAGE AREA
SCALE 1"=1000'
80-22-002
SHEET 2 OF 17
80-22-002

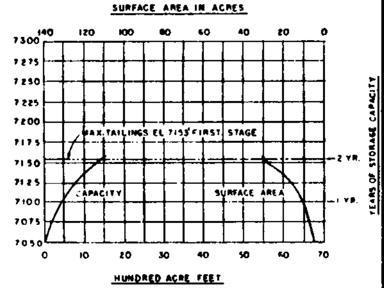
ranging in size to large boulders. A thin bed of clay is also found in the right abutment, downstream from the centerline of the dam. Overlayed by the colluvium is a limestone formation. This rock is fractured and jointed having a high permeability. The only exception is in the upstream foundation area where the Manning Canyon shale outcrops instead of the limestone. The contact between limestone and shale has been studied in some detail using borings, seismic refraction, and geologic mapping.

No foundation investigation has been performed for the saddle dam. Consequently, its final position and design is subject to a possible change depending on foundation conditions. The saddle dam will have an ultimate height of 85 feet. Except for its smaller size, the final design cross-sections of the saddle dam is expected to be indentical to that of the main dam. Its construction will be staged following the same scheme outlined for the main dam. The same criteria have been applied for the design of both dams.

The embankment design consists of a zoned embankment with an upstream inclined core shown in Figure 1.3. The 1.5 to 1 upstream slope will consist of sandy to clayey gravel with boulders and cobbles. The core material is composed of broken-down Manning Canyon shale and clay from the impoundment area. Figures 1.4, 1.5 and 1.6 shows the borrow


BASE LINE & ℄ OF THIRD STAGE DAM
8'-0" FREEBOARD
4'-0" STORM WATER STORAGE PLUS WAVE PROTECTION
TOP OF TAILINGS
REMOVE TOP 3'-0" FROM EXISTING DAM
T.O. CREST EL. 7260'
ZONE I-DOWNSTREAM SHELL COVER
ZONE II-DOWNSTREAM SHELL
EXISTING GROUND LINE
SOUND ROCK LINE
SECTION A 1"=100' 80-22-005
THIRD STAGE 12-YEARS
82'-6"
85'-0"
9'-0" FREEBOARD
5'-0" STORM WATER STORAGE PLUS WAVE PROTECTION
TOP OF TAILINGS
T.O.CREST EL. 7215'
REMOVE TOP 3'-0" FROM EXISTING DAM
ZONE VI-UPSTREAM SHELL
ZONE II DOWNSTREAM SHELL
EXISTING GROUND LINE
SOUND ROCK LINE
SECTION B 1"=100' 80-22-004
SECOND STAGE 6-YEARS
157'-6"
125'-0"
12-0" FREEBOARD
8'-0" STORM WATER STORAGE PLUS WAVE PROTECTION
TOP OF TAILINGS
T.O.CREST EL. 7165'
ZONE VI-UPSTEAM SHELL
ZONE II-DOWNSTREAM SHELL
EXISTING GROUND LINE
ZONE V IMPERVIOUS CORE
SOUND ROCK LINE
6" PIPE TO SEEPAGE POND MINIMUM SLOPE OF 1% (TYP.)
ZONE IV - FINE FILTER
ZONE III-COARSE FILTER
BACKFILL OR SHAPE AS REQUIRED TO PROVIDE DRAINAGE
SECTION C 1"=100' 80-22-003
FIRST STAGE 2-YEARS
MAIN DAM
BASE LINE & ℄ OF THIRD STAGE DAM
8'-0" FREEBOARD
4'-0" STORM WATER STORAGE PLUS WAVE PROTECTION
TOP OF TAILINGS
T.O. CREST EL. 7260'
ZONE VI- UPSTREAM SHELL
REMOVE TOP 3'-0" FROM EXISTING DAM
ZONE I-DOWNSTREAM SHELL COVER
ZONE II-DOWNSTREAM SHELL
EXISTING GROUND LINE
SOUND ROCK LINE
SECTION D 1"=100' 80-22-005
THIRD STAGE 12-YEARS
ZONE II-DOWNSTREAM SHELL
6" PIPE, TRENCH TO DAYLIGHT, MIN. SLOPE OF 1% (TYP.)
82'-6"
85'-0"
9'-0" FREEBOARD
5'-0" STORM WATER STORAGE PLUS WAVE PROTECTION
TOP OF TAILINGS
T.O.CREST EL. 7215'
SOUND ROCK LINE
ZONE III-COARSE FILTER
ZONE IV-FINE FILTER
ZONE VI-UPSTREAM SHELL
ZONE V IMPERVIOUS CORE
SECTION E 1"=100' 80-22-004
SECOND STAGE 6-YEARS
SADDLE DAM
30'-0"
15'-0" ℄ DAM
10'-0" 5'-6"
ZONE I-DOWNSTREAM SHELL COVER
ZONE IV-FINE FILTER
ZONE III COARSE FILTER
ZONE II-DOWNSTREAM SHELL
ZONE VI UPSTREAM SHELL
ZONE V-IMPERVIOUS CORE
DETAIL 1 1"=10'
NOTE:
1. FOR SPECIFICATIONS OF ZONE MATERIAL SEE SPECIFICATION NO. S-2.
FIGURE 1.3
MERCUR GOLD PROJECT
TOOELE COUNTY
GETTY MINING COMPANY
Salt Lake City, Utah
Davy McKee
DMC Engineers and Constructors
San Mateo, California
RESERVATION CANYON TAILINGS DISPOSAL DAMS CROSS-SECTONS
AS NOTED
SC 2385 A
80-22-006
SHEET 6 OF 17





CAPACITY-AREA CURVES

TAILINGS DISPOSAL RESERVOIR

TAILING RESERVOIR CAPACITY TABLE

CONTOUR	AREA ACRES	AVERAGE AREA	CAPACITIES: INCREMENTAL ACRE-FT	CAPACITIES: TOTAL ACRE-FT	CAPACITIES: TOTAL CU. YD.
7050	6.18				
	-	7.065	176.6		
7075	7.95			176.6	284,900
		9.170	229.2		
7100	10.39			405.9	654,852
		12.500	312.5		
7125	14.61			718.4	1159018
		22.025	616.7		
7153	29.44			1335.1	2153961
		30.665	214.7		
7160	31.89			1549.8	2,500,271

STORM WATER STORAGE — 214.7 ACRE FT

½ PMF — 200.0 ACRE FT.

½ WAVE HEIGHT = 0.82 FT (70 MPH)
1.00 FT. PROVIDED

✦ GROUND WATER MONITOR WELLS SEE SPECIFICATIONS.

FIGURE 1.4

MERCUR GOLD PROJECT
TOOELE COUNTY
GETTY MINING COMPANY
Salt Lake City, Utah

Davy McKee
DMC Engineers and Constructors
San Mateo, California

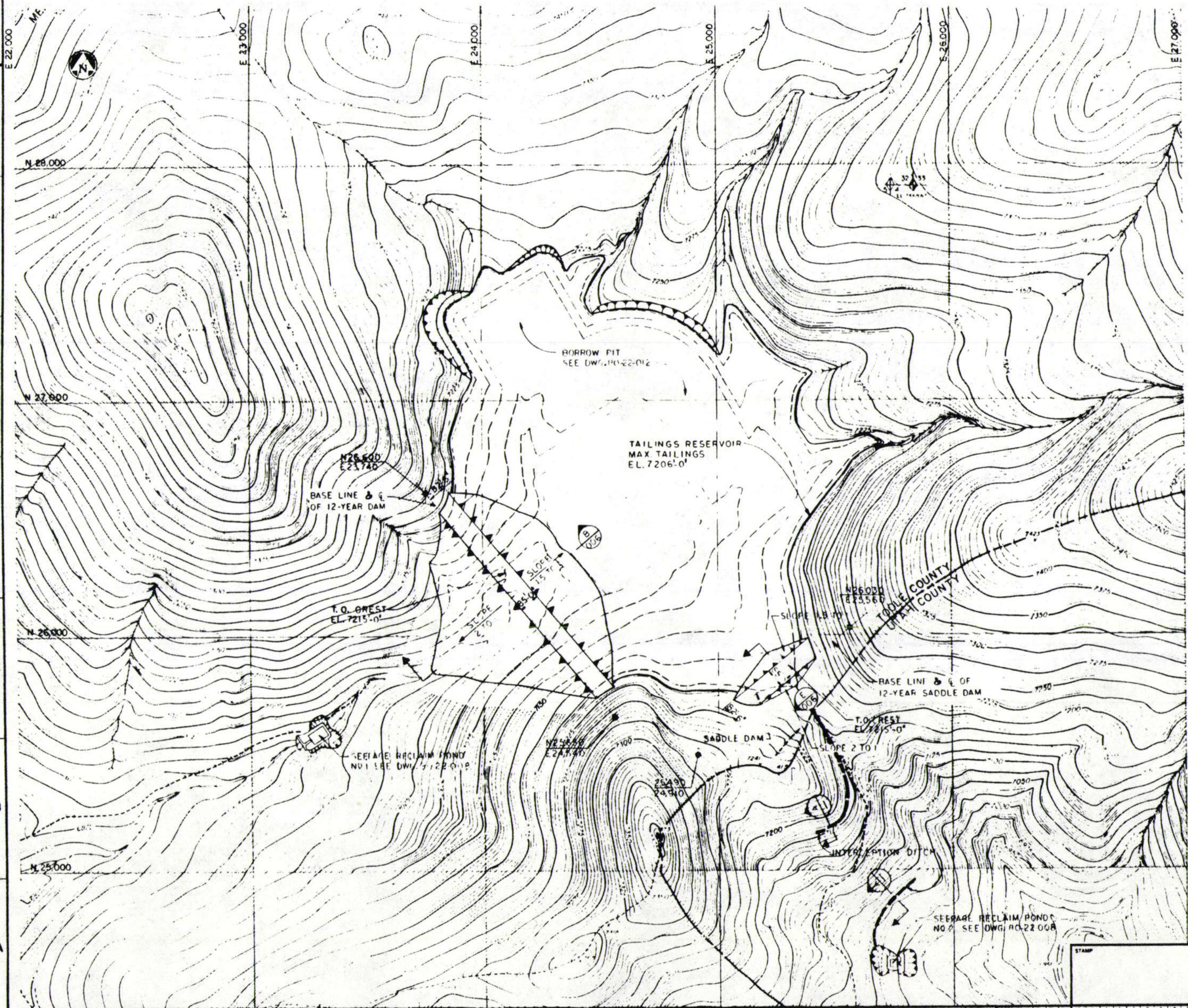
RESERVATION CANYON
TAILINGS DISPOSAL DAM
PLAN FIRST STAGE 2-YEARS

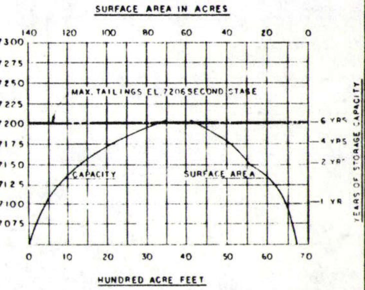
SCALE 1" = 200'
5C2385A
80-22-003
SHEET 3 OF 17

ISSUED FOR APPROVAL
ISSUED FOR BID

80-22-003

80-22-004





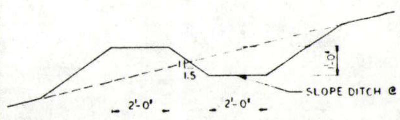
CAPACITY-AREA CURVES

TAILINGS DISPOSAL RESERVOIR

TAILING RESERVOIR CAPACITY TABLE

CONTOUR	AREA ACRES	AVERAGE AREA	CAPACITIES INCREMENTAL ACRE-FT	TOTAL ACRE-FT	TOTAL CU. YD.
7050	6.18				
		7.065	176.6		
7075	7.95			176.6	[illegible]
		9.170	229.25		
7100	10.39			[illegible]	[illegible]
		12.500	312.50		
7125	14.61			718.4	[illegible]
		21.500	537.5		
7150	28.39			1256.0	[illegible]
		32.76	[illegible]		
7175	37.13			[illegible]	3347667
		47.68	[illegible]		
7206	58.23			[illegible]	[illegible]
		58.795	205.78		
7209.5	59.36			3759.18	[illegible]

STORM WATER STORAGE — 205.78 ACRE FT.
½ PMF — 200.0 ACRE FT.
½ WAVE HEIGHT = 1.11 FT (70 MPH)
1.25 FT PROVIDED



TYPICAL INTERCEPTION DITCH

SECTION A

FIGURE 1.5

MERCUR GOLD PROJECT
TOOELE COUNTY
GETTY MINING COMPANY
Salt Lake City, Utah

Davy McKee
DMC Engineers and Constructors
San Mateo, California

RESERVATION CANYON
TAILINGS DISPOSAL DAM
PLAN SECOND STAGE 6-YEARS

SCALE 1" = 200'
SC2385A
DRAWING No. 80-22-004
SHEET 4 OF 17

REVISIONS: A ISSUED FOR APPROVAL

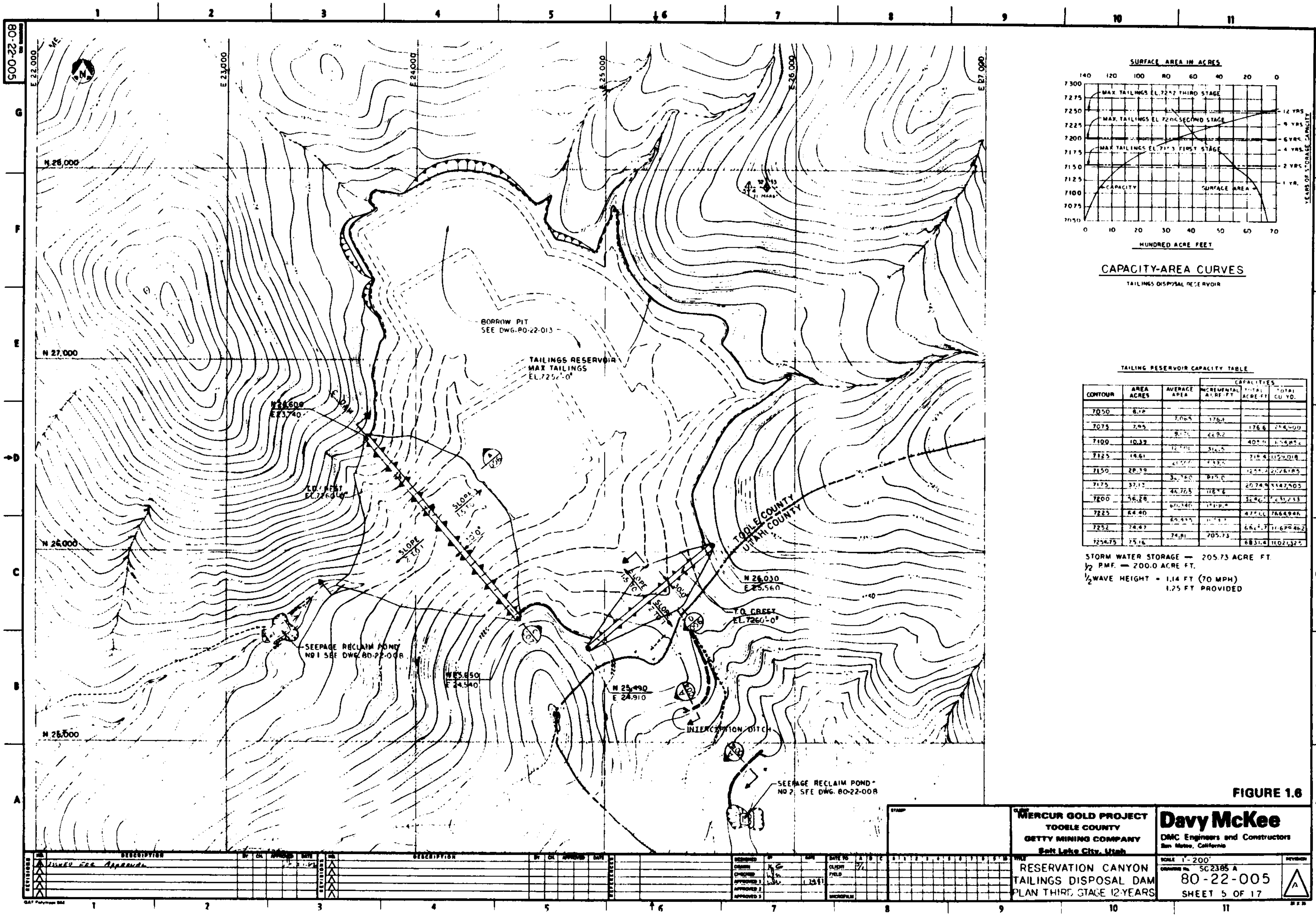


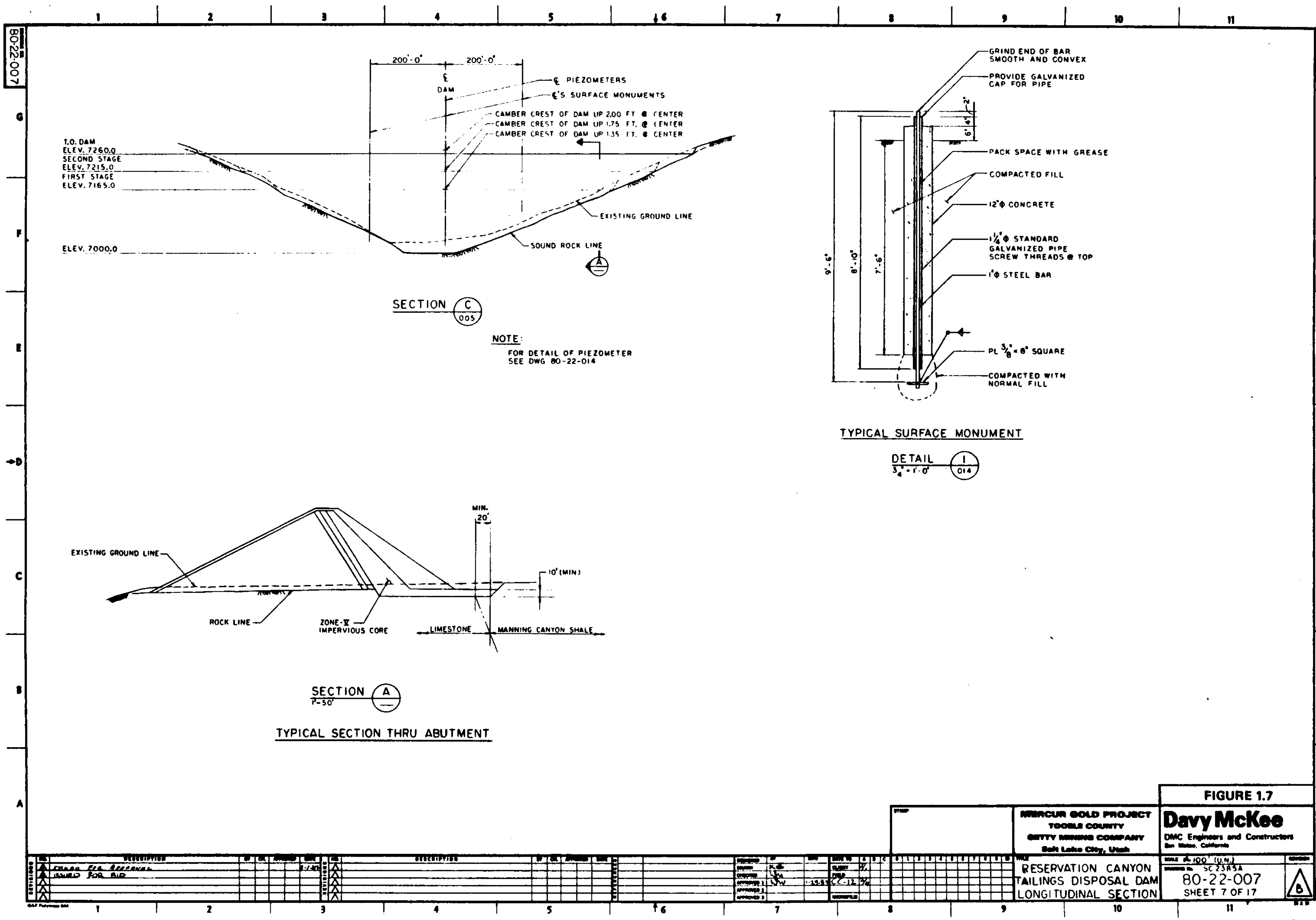
FIGURE 1.6
MERCUR GOLD PROJECT
TOOELE COUNTY
GETTY MINING COMPANY
Salt Lake City, Utah
Davy McKee
DMC Engineers and Constructors
San Mateo, California
RESERVATION CANYON
TAILINGS DISPOSAL DAM
PLAN THIRD STAGE 12 YEARS
SCALE 1"=200'
SC2385 A
80-22-005
SHEET 5 OF 17
80-22-005
ISSUED FOR APPROVAL
CAPACITY-AREA CURVES
TAILINGS DISPOSAL RESERVOIR
SURFACE AREA IN ACRES
HUNDRED ACRE FEET
MAX TAILINGS EL 7252 THIRD STAGE
MAX TAILINGS EL 7205 SECOND STAGE
MAX TAILINGS EL 7175 FIRST STAGE
CAPACITY
SURFACE AREA
YEARS OF STORAGE CAPACITY
12 YRS
9 YRS
6 YRS
4 YRS
2 YRS
1 YR.
TAILING RESERVOIR CAPACITY TABLE
CONTOUR
AREA ACRES
AVERAGE AREA
CAPACITIES
INCREMENTAL AC. FT.
TOTAL ACRE FT
TOTAL CU. YD.
STORM WATER STORAGE — 205.73 ACRE FT.
1/2 PMF — 200.0 ACRE FT.
1/2 WAVE HEIGHT = 1.14 FT (70 MPH)
1.25 FT PROVIDED
BORROW PIT
SEE DWG. 80-22-013
TAILINGS RESERVOIR
MAX TAILINGS
EL 7252'-0"
T.O. CREST
EL 7260'-0"
SLOPE
SEEPAGE RECLAIM POND
NO 1 SEE DWG. 80-22-008
SEEPAGE RECLAIM POND
NO 2 SEE DWG. 80-22-008
INTERCEPTION DITCH
TOOELE COUNTY
UTAH COUNTY
N 26,030
E 25,560
N 25,490
E 24,910
N 25,850
E 24,540
N 26,600
E 23,740
N 28,000
N 27,000
N 26,000
N 25,000
E 22,000
E 23,000
E 24,000
E 25,000
E 26,000
E 27,000

area for the core material. Filter materials shall be borrowed from outside the project area. The downstream shell consists of sandy to clayey gravel with boulders and cobbles. The downstream slope shall be protected from erosion by an 10 foot wide strip of rockfill having a maximum particle size of 1 foot. The downstream slope shall be 2 horizontal to 1 vertical. See Figure 1.7.

Hydrologically, the site is in a semi-arid area. Annual evaporation exceeds annual precipitation. The Probable Maximum Precipitation (PMP) for a duration of (24 hr.) is 10.5 inches and was determined using data from the U.S. Water Bureau (34). Based on the PMP, the Probable Maximum Flood (PMF) was determined. The embankment is designed to store one-half of the PMF. This is conservative because its probability of exceedence over a period of 12 years is less than 1.12%. No diversion ditches are planned for precipitation runoff, since the dam will always have enough freeboard to impound runoff.

Construction of intermediate stages will be started in time to maintain, at all times, sufficient freeboard to store safely runoff from the design storm.

Seismically, the area of the site is in an area of high seismic risk. The primary fault zone is the Wasatch Fault. This fault is considered capable of generating a


80-22-007
200'-0"
200'-0"
℄ DAM
℄ PIEZOMETERS
℄'S SURFACE MONUMENTS
CAMBER CREST OF DAM UP 2.00 FT @ CENTER
CAMBER CREST OF DAM UP 1.75 FT. @ CENTER
CAMBER CREST OF DAM UP 1.35 FT. @ CENTER
T.O. DAM
ELEV. 7260.0
SECOND STAGE
ELEV. 7215.0
FIRST STAGE
ELEV. 7165.0
EXISTING GROUND LINE
ELEV. 7000.0
SOUND ROCK LINE
SECTION C 005
NOTE:
FOR DETAIL OF PIEZOMETER
SEE DWG 80-22-014
GRIND END OF BAR SMOOTH AND CONVEX
PROVIDE GALVANIZED CAP FOR PIPE
PACK SPACE WITH GREASE
COMPACTED FILL
12"Φ CONCRETE
1¼"Φ STANDARD GALVANIZED PIPE SCREW THREADS @ TOP
1"Φ STEEL BAR
PL ⅜" × 6" SQUARE
COMPACTED WITH NORMAL FILL
9'-6"
8'-10"
7'-6"
6"
4"
2"
TYPICAL SURFACE MONUMENT
DETAIL 1 014
¾" = 1'-0"
EXISTING GROUND LINE
MIN. 20'
10' (MIN)
ROCK LINE
ZONE-V IMPERVIOUS CORE
LIMESTONE
MANNING CANYON SHALE
SECTION A
1"=50'
TYPICAL SECTION THRU ABUTMENT
FIGURE 1.7
MERCUR GOLD PROJECT
TOOELE COUNTY
GETTY MINING COMPANY
Salt Lake City, Utah
Davy McKee
DMC Engineers and Constructors
San Mateo, California
RESERVATION CANYON
TAILINGS DISPOSAL DAM
LONGITUDINAL SECTION
SC 2385A
80-22-007
SHEET 7 OF 17
ISSUED FOR BID

1.0 INTRODUCTION (cont'd)

magnitude 7.5 earthquake. However, it has not produced any significant earthquake (M = 5 to 5.5) during the last 133 years -- the period of historical earthquake records. A lower bound for a hypothetical earthquake generated by this fault would have a magnitude of 6.5. If this earthquake were to originate on the Wasatch Front (the fault segment closest to the site), the focal distance would be approximately 35 kms.

Another fault of concern is the West Mercur Fault located at the mouth of Mercur Canyon four miles west of the site. Examination of the fault scarp indicates that it has been formed by events of approximately magnitude 7 (32).

Limit equilibrium slope stability analysis has been performed to check the embankment stability against rotational slides under end of construction conditions and for full reservoir conditions under both static and earthquake loadings.
A seismic coefficient of 0.1g was used in pseudo-static earthquake analysis.

A simplified deformation analysis was performed to evaluate approximate permanent displacement due to: a magnitude 7.5 earthquake originated at the Wasatch Fault and a magnitude 7.0 earthquake originated at the West Mercur Fault. Based on these analyses, we estimate deformations of the order of

1.0 INTRODUCTION (cont'd)

1 foot for the Wasatch earthquake and 3 feet for the West Mercur earthquake. These displacements can be tolerated by the dam structure without complete failure since seismic resistant features (e.g. relatively wide filters and core) have been included in design.

A monitoring program will be implemented to monitor movement and pore pressures during construction and operation. Should any anomaly be detected, the design shall be checked under the unexpected conditions, and remedial measures taken, if needed.

During construction, piezometers shall be read daily, and monuments shall be surveyed once a month. During operation, piezometers shall be read monthly.

A mathematical model was developed to describe the seepage zone from the tailings pond. Contaminant attenuation and natural degradation of cyanide was described. The impact of the historic tailings was addressed. The nearest springs and wells were identified. There will be monitoring wells installed around the tailings pond which will be inspected on a regular basis.

1.2 Site Location and Description

The proposed tailings impoundment facility is located in the northeast quarter of Section 5 in Township 6 South, Range 3 West, Salt Lake Base and Meridian. This site is an unpopulated drainage basin 5 miles west of Cedar Fort and 4 miles south of Ophir, the closest towns. The impoundment area is to occupy Reservation Canyon, a seasonal drainage course just northeast of the abandoned town of Mercur, as shown on Figures 1.1 and 1.2. The embankment will be constructed across a narrow section of the canyon. In the vicinity of the embankment, the canyon walls are moderately steep with maximum slopes being on the order of 1.5 horizontal to 1.0 vertical. At elevation 7260 feet (maximum dam elevation) the canyon width is approximately 1250 feet. The impoundment area essentially consists of the head of Reservation Canyon where the drainage course widens and divides into a system of relatively small, individual drainages. At its maximum projected elevation, the impoundment area occupies approximately 74.5 acres. Two relatively low saddle areas are noted along the northern and southern perimeters of the impoundment area. The minimum elevation of the northern saddle area is approximately 7368 feet, while the southern saddle has a minimum elevation of 7207.5 feet.

Vegetation within the area generally consists of a moderate growth of brush and small trees.

2.0 DESIGN CRITERIA

2.1 Scope

This design criteria establishes the basic parameters for the design and permit submissions for the Mercur Gold Project tailings dam and associated structures, located at Reservation Canyon. Criteria additional to those listed below have been developed for the State Engineer.

2.2 Design Life

The design life for the active tailings pond will be 12 years. The required storage volume as specified by Getty Mining Company as:

1 million cubic yards for the first year

0.8 million cubic yards for each of the remaining years

9.8 million cubic yards of tailings will be impounded by the end of operation.

2.3 Regulatory Requirements

Permits are required for the construction of the Mercur Gold Project tailings dam. Approval of plans and specifications for the tailings dam construction will be processed through the following Utah State Agencies:

Utah Department of Natural Resources

Utah Department of Health

2.0 DESIGN CRITERIA (cont'd)

The Submission to the Department of Natural Resources will cover their requirements for:

Review of the tailings dam design, slope stability, safety, and long term monitoring, as well as construction plans, specifications and construction control through the Division of Water Rights, Office of the State Engineer.

The submission to the Department of Health will cover their requirements for review of the tailings dam and impoundment design with regard to possible discharge of pollutants to the environment (ground water and air). This review will be carried out by the Bureau of Water Pollution control.

Final reclamation plans have been approved prior to the preparation of this document by the Division of Gas, Oil, and Mining.

2.4 Hydrology

The storage capacity of each stage of the dam will accommodate 1/2 the volume of PMF (probable maximum flood) in addition to the tailings storage.	Office of State Engineer

No spillway will be provided for the embankment. The PMF will be determined from the 24-hr. Probable Maximum Precipitation (PMP).

2.0 DESIGN CRITERIA (cont'd)

PMP = 10.5 inches — US Weather Bureau

10 year 24 hour storm precipitation = 1.78 in.

2.5 Embankment Design Criteria

2.5.1 Embankment Construction:

The embankment will be constructed in the following stages:

Stage I - The embankment shall be capable of safely storing 1.8 million cubic yards of tailings. See Figure 1.4.

Stage II - The embankment shall be capable of safely storing 5.0 million cubic yards of tailings. See Figure 1.5.

State III - This completes the embankment. The total capacity is 9.8 million cubic yards of safely stored tailings. See Figures 1.6 and 1.7.

2.5.2 Embankment Freeboard:

Each stage of the embankment shall be designed to include freeboard to store the design flood plus 1.5 times the wave height plus an additional 4 ft. to account for crest damage due to frost penetration and safety factor. Freeboard is defined as the vertical distance between the crest of the dam and the normal operating pool level.

2.5.3 Embankment Settlement:

The embankment settlement is estimated as 0.8 percent of its total design height. Consequently, allowance shall be made for this expected settlement during construction, particularly during the final stage.

2.5.4 Impervious Core Thickness

The core width, at any depth, shall be 25 to 40 percent of the design water head above it. The actual thickness will depend on the availability, quality, and cost of the core material. See Figure 1.3.

3.0 GEOLOGY

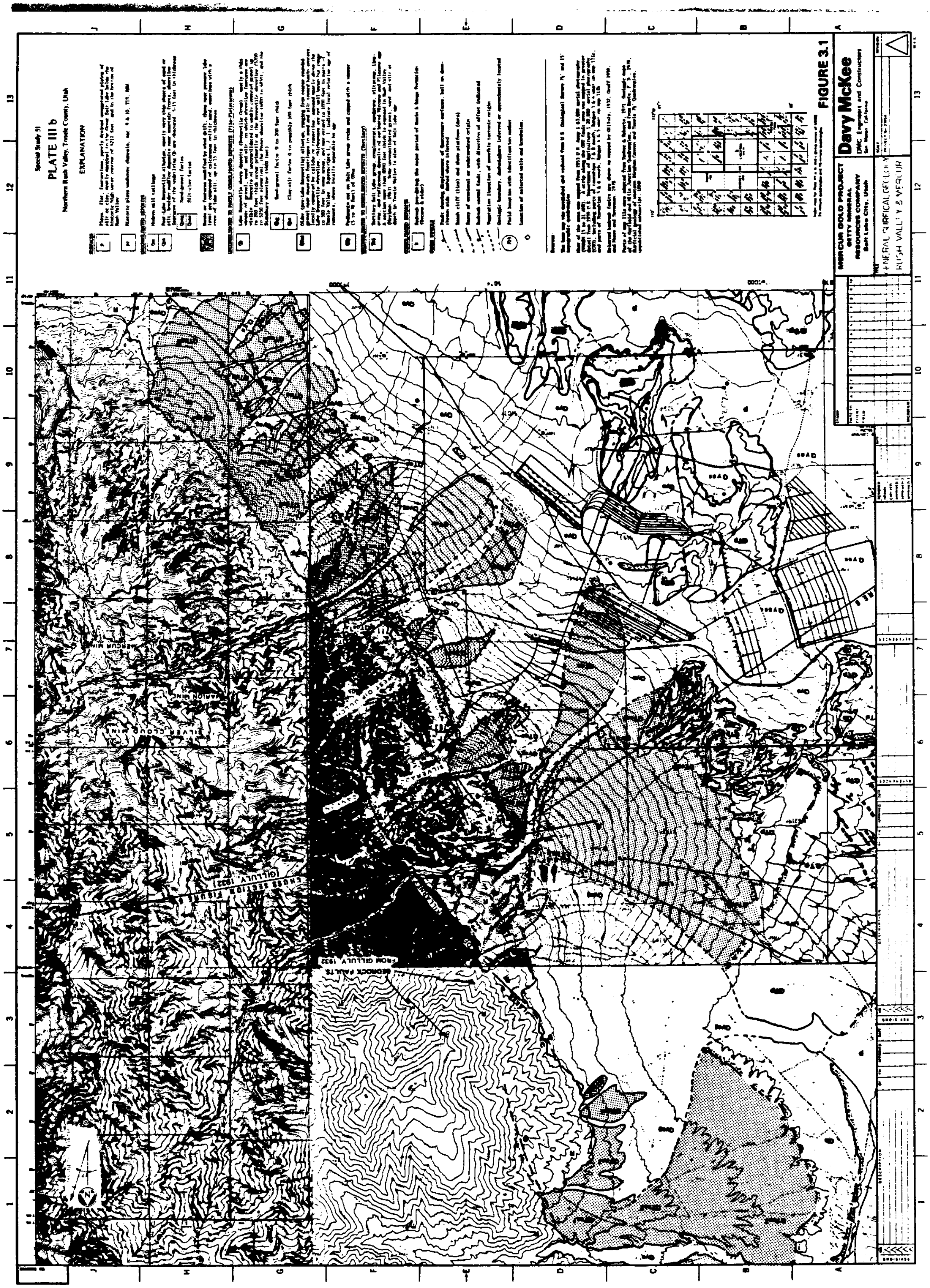
3.1 Regional Geology

The proposed dam site in Reservation Canyon is located in the southern Oquirrh Mountains, a generaly north-south trending range approximately 30 miles long by 6 to 12 miles wide. This fault block mountain range is in the eastern portion of the Basin and Range structural province west of the Wasatch Range and east-southeast of the town of Tooele, Utah. Figure 3.1 shows the generalized surface geology of the area of the site.

3.2 Stratigraphy

The bedrock in the vicinity of the dam site includes Paleozoic and Mesozoic limstones, quartzites and shales and Eocene igneous rocks.

The principal geological units exposed at the site are upper Great Blue limestone, the Manning Canyon shale and the basal Oquirrh Formation. The upper Great Blue limestone (Mgbu) (upper Mississippian) consists of a monotonous 2750 foot thick sequence of massive bedded, medium to dark grey and blue grey, aphaic to finely crystalline limestones which overlie the medial Long Trail shale member (2). This is in turn overlain by the Manning Canyon shale (MPmc) (Mississippian-Pennsylvanian), a black, thinly bedded, recessive carbonaceous to calcareous shale with interbedded



Special Study 51
PLATE III b
Northern Rush Valley, Tooele County, Utah
EXPLANATION
FIGURE 3.1
Davy McKee
DMC Engineers and Constructors
MERCUR GOLD PROJECT
GETTY MINERAL
RESOURCES COMPANY
Salt Lake City, Utah
BEDROCK FAULTS
FROM GILLULY 1932

limestone and quartzite. The average thickness of the Manning Canyon shale is 1500-1600 feet (20). It is gradationally overlain by the Hall Canyon member of the Oquirrh Formation (Phc) (Pennsylvanian), which consists of approximately 900 feet of dark to medium brown-grey bioclastic and crystalline limestones with local orthoquartzites.

Igneous rocks in the Mercur area include stocks, sills and dikes of grandioritic to rhyolitic compositions emplaced during early tertiary time. The nearest igneous rock, the Eagle Hill Rhyolite porphyry, crops out about one mile south of the dam site.

3.3 Structure

During Laramide deformation (approximately 65 million years ago) the sedimentary strata were folded into a series of large, generally north-northwest trending anticlines and synclines. The proposed dam site is situated on the eastern flank of the Ophir Anticline, approximately 1.9 miles east-northeast of the fold axis. The Pole Canyon Syncline fold axis lies east of the dam site.

Some faulting observed in the area is attributed to the Laramide folding (23). Other faults evident in the area are associated with the Eocene igneous activity. The third and most significant fault system developed in the area is the Basin and Range structural deformation.

3.0 GEOLOGY (cont'd)

The main phase of normal faulting of the Basin and Range structural deformation began in Miocene time. The west Mercur Fault which forms the western boundary of the Oquirrh Mountains and is located approximately 4 miles S 70°W of the dam site, is related to this event. Both the West Mercur Fault and the Wasatch Fault, located parallel to and east of the Mercur Fault, exhibit evidence of recent activity (8, 13 and 29). See Figure 3.2.

3.4 Local Geology

Preliminary geologic mapping of the dam site was done by Woodward Clyde Consultants in November and December, 1981. (33) See Figure 3.2.

The majority of the proposed dam footprint in Reservation Canyon will overlay the upper Great Blue limestone. At this location, the upper Great Blue is hard, strongly jointed rock with open partings along bedding places (31). The average bedding strike is N 22° with an average dip of 45°N. The dominant joint orientation is a north-easterly strike with a vertical dip.

The southeast side of the dam footprint and most of the proposed reservoir is underlain by the Manning Canyon shale. The contact between the Great Blue limestone and the Manning Canyon shale is defined on the basis of calcareous shale being the dominat rock type over dark blue-grey

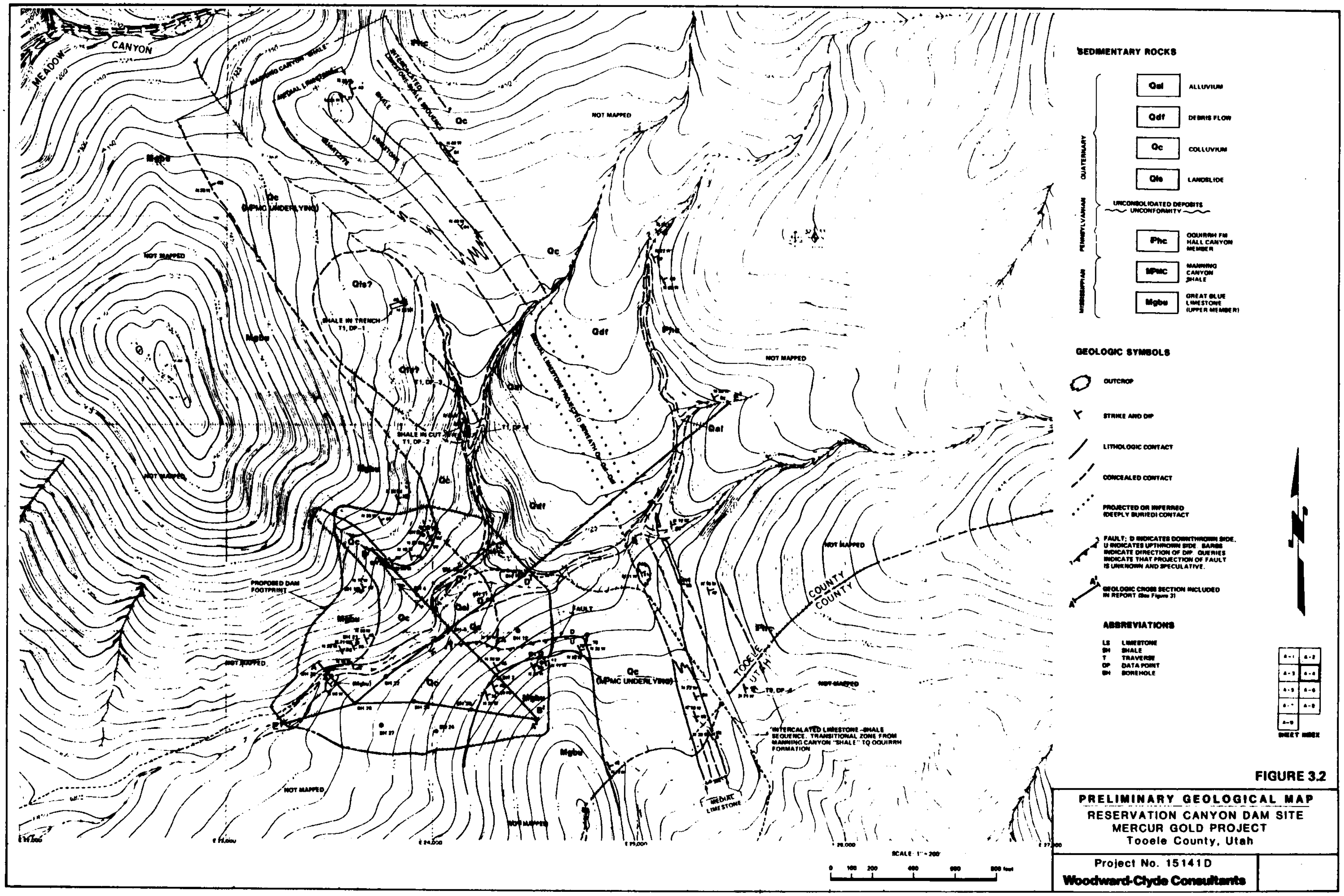


FIGURE 3.2

PRELIMINARY GEOLOGICAL MAP
RESERVATION CANYON DAM SITE
MERCUR GOLD PROJECT
Tooele County, Utah

Project No. 15141D

Woodward-Clyde Consultants

limestones. The shale unit is a valley-former and the majority of it is covered by colluvium and/or alluvium. Secondary calcite and quartz stringers are evidence of hydrothermal alteration. The strike and dip of this unit is variable although in general it is similar to the Great Blue limestone. This variability of dip may be explained by increased deformation during folding resulting from the location of the shale between two thick and competent limestone strata.

Interbeds of limestone and quartzite exist within the Manning Canyon shale. One such medial sequence, 100 to 400 feet thick, was identified within the reservoir area (33).

Most of the site is covered by colluvium and/or alluvium. The coluvium is generally rocky whereas the alluvium is finer grained. These unconsolidated deposits range in thickness from 10-20 feet on the slopes beneath the proposed dam abuttment to 20-80 feet along the valley floor. A maximum thickness of 102 feet was encounterd at one test site (31).

A 50-60 foot thick heterogenous, rock debris deposit covers a major portion of the reservoir floor.

3.0 GEOLOGY (cont'd)

3.4.1 Local Faulting

Within reservation Canyon, strong linears are evident on an aerial photograph of the area. A probable explanation of these generally east-west trending, subparallel features is that they represent fault zones.

One of these fault zones crosses the dam foundation area, according to Woodward-Clyde investigations, putting the Manning Canyon "in fault contact with the Great Blue limestone beneath part of the upstream toe area" (31). No openings were observed in the fault zone but "the true nature and extent of the fault ... is still poorly known:" (33). This will be clarified during the foundation excavation.

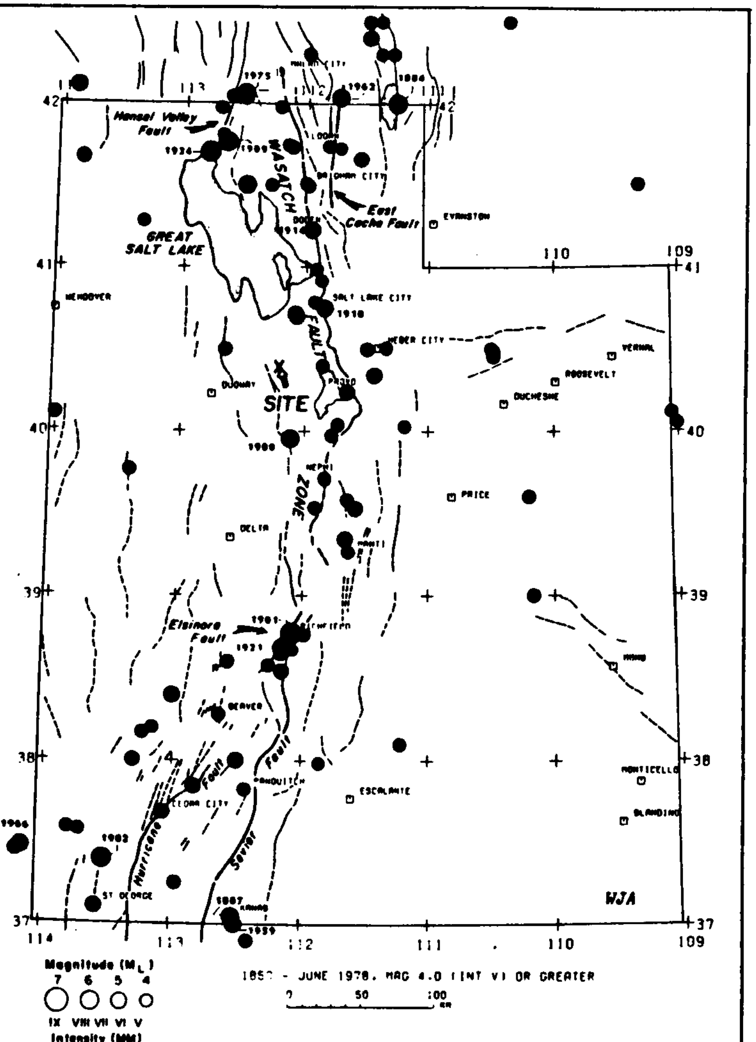
These inferred faults are transverse to the trend of the potentially active faults in the region (Wasatch and West Mercur), i.e. they do not appear to be part of the same fault system. Their orientation is more analagous to faults associated with the Laramide deformation.

4.0 SEISMICITY AND FAULTING

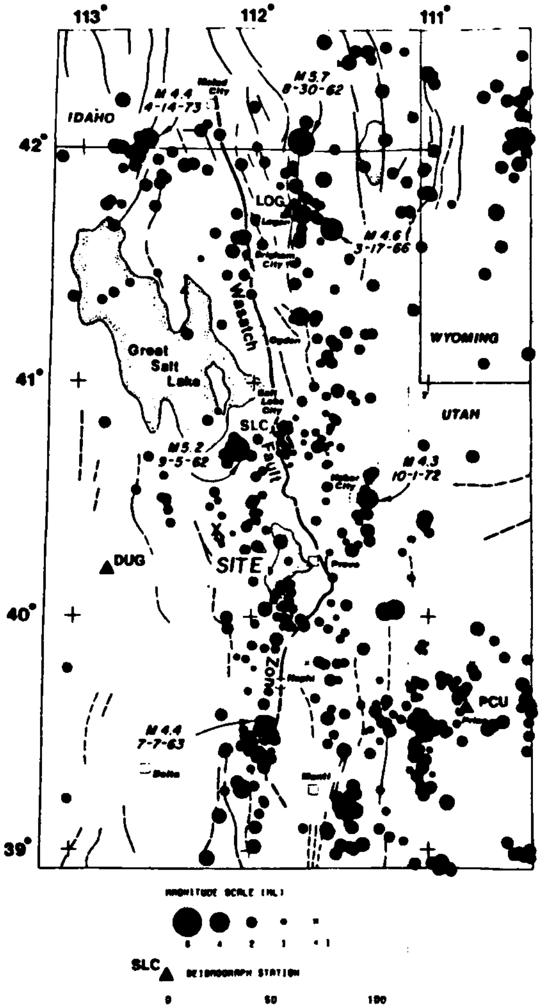
4.1 Active Faults and Seismic History

The site area lies along the western edge of the Intermountain Seismic Belt, a north-trending zone of seismicity interpreted as the boundary between two subplates of the North American Plate. The belt extends along the boundary between the Rocky Mountain and the Colorado Plateau physiographic provinces on the east and the Basin and Range physiographic province to the west from southwestern Utah to the Canadian border.

In the Utah area, the Intermountain Seismic Belt is delineated by a series of active fault zones. The primary fault zone in this area is the 370-mile long Wasatch fault which extends from Gunnison, Utah, northward to Malad city, Idaho. The Wasatch fault passes through Salt Lake city along the geologic break referred to as the Wasatch Front. Other active fault zones in the Utah area included the Hansel Valley fault to the north and the Sevier, Hurricane and Elsinore fault systems to the south. The general seismicity of these fault zones is demonstrated by concentration of earthquake epicenters presented on Figure 4.1. A list of earthquakes which may have affected Tooele and Rush Valleys is shown in Table 4.1 (8).



EPICENTER MAP OF THE LARGEST HISTORICAL EARTHQUAKES IN THE UTAH REGION, 1850-1978



WASATCH FRONT EQ'S : JULY 62 TO SEPT. 74

EARTHQUAKE EPICENTERS

FIGURE 4.1

Dames & Moore

REFERENCE:
EARTHQUAKE STUDIES IN UTAH, 1850 TO 1978, EDITED BY WALTER J. ARABASZ, ROBERT B. SMITH, AND WILLIAM D. RICHINS, PREPARED AS A SPECIAL PUBLICATION OF THE UNIVERSITY OF UTAH SEISMOGRAPH STATIONS, JULY 1979.

BY ______ DATE ______
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REVISIONS
BY ______ DATE ______ TO EO ______
BY ______ DATE ______ TO EO ______

TABLE 4.1

CHECK LIST OF EARTHQUAKES (8)
WHICH MAY HAVE AFFECTED THE TOOELE AND RUSH VALLEYS

Date	Local Time	Epicentral Location	Epicentral Intensity (MM)	Felt Area Sq. Mi.	Description
8-01-00	00-45	Eureka	VII	<1,000	Slight damage in epicentral area (Deseret News)
10-05-09	19-50	Hansel Valley	VII	30,000	Buildings out of plumb at Saltair; waves washed over Lucin Cutoff (Deseret News) no mention (Tooele Transcript-Bulletin)
5-22-10	07-28	Salt Lake City	VII	<1,000	"Salt Lake rocked by earthquake" -- no mention of local effect (Tooele Transcript-Bulletin).
8-11-15	03-20	Stansbury Range	V	<1,000	No mention (Tooele Transcript-Bulletin).
10-02-15	23-56	Pleasant Valley, Nev.	X	30,000	"Earthquake in Nevada" -- no mention of local effect (Tooele Transcript-Bulletin).
3-12-34	08-06	Kosmo	IX	170,000	No mention of Tooele, slight damage in Grantsville (Tooele Transcript-Bulletin), 3/16/34); intensity V with slight damage in Tooele (Neumann 1936).
11-18-37	09-50	Lucin	VI	<1,000	Not mentioned in (Tooele Transcript-Bulletin).
6-30-38	06-37	Magna	V	<1,000	No mention, (Tooele Transcript-Bulletin).

Table 4.1 (cont'd)

Date	Local Time	Epicentral Location	Epicentral Intensity (MM)	Felt Area Sq. Mi.	Description
12-01-58	13-51 &20-23	Clover ? (Probably Nephi)	V	<1,000	No mention, (Tooele Transcript or Bulletin).
9-05-62	09-04	Magna	VI	<1,000	"Another quake shakes ---" felt locally but no damage (Tooele Transcript); no mention (Tooele Bulletin).
9-23-67		Magna	V	<1,000	No mention, (Tooele Transcript).
3-27-75	08-31	Pocatello Valley	VII	-	No mention (Tooele Transcript-Bulletin).

SOURCES: Rogers and others, 1976; Richins, 1979; Williams and Tapper, 1953; Neumann, 1936; Deseret News; Tooele Transcript and Tooele Bulletin and their successors.

4.0 SEISMICITY AND FAULTING (cont'd)

In the immediate dam site area, the largest seismic events include a magnitude 5.2 eathquake which occurred near Magna, Utah (approximately 20 miles to the north) on September 5, 1962; a magnitude 5.5 event which occurred near Eureka, Utah (approximately 50 miles to the south) August 1, 1900; and a 4.2 event which occurred in the Stansbury Mountains. The largest recorded seismic event which has occurred in the Salt Lake City area was magnitude 5.5 event occurring on May 22, 1910. (8).

The closest potentially active fault is the West Mercur Fault four miles southwest of the dam site. See Figure 3.2. This is a "range front" fault caused by west-trending extensional stresses during the past few million years. Evidence of Quartesnary surface faulting (8) suggests at last two fault movements between 12,000 and 6,000 years ago. After review of aerial-photography and other geological and seismological data by Woodward Clyde Consultants concluded that no appreciable movement has occurred during the last 2000 years. The return period for this fault is estimated at about 5000 to 6,000 years (32).

The Wasatch Fault has been studied recently (6, 29). Results from these studies indicate that this fault is capable of producing a magnitude 7.5 eathquake during a maximum estimated return period of 430 years. These results are based on detailed geological and seismological work and are not substantiated by recent historical data. There has been no earthquake of significant magnitude (M = 5 to 6) generated by the Wasatch Fault over the last 133 years, the period of documented seismic history.

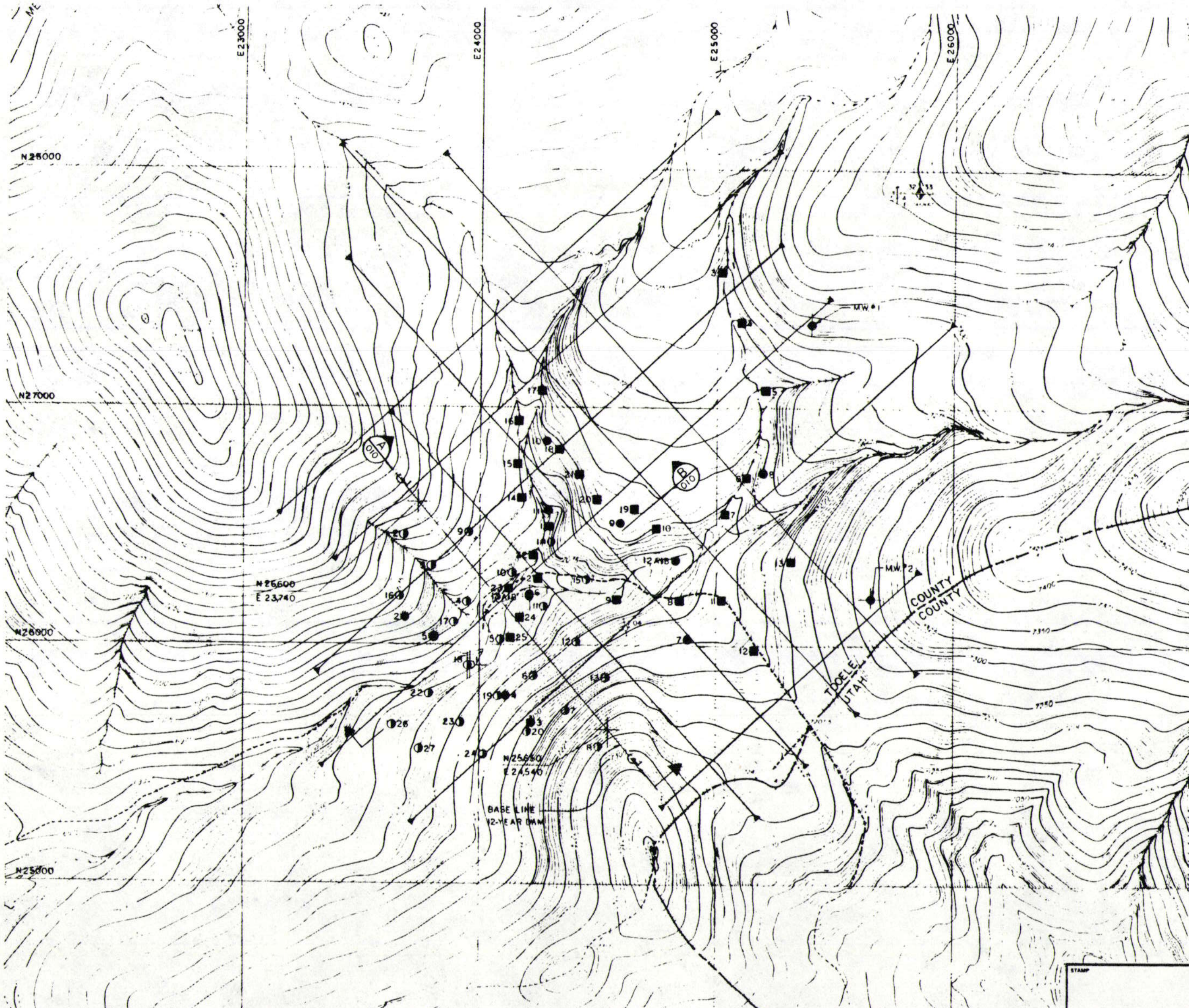
4.2 Design Earthquakes

As a reault of reviewing the seismic data for this region, two possible sources of critical seismic loading are postulated for the purpose of earthquake analysis:

A magnitude 7.5 earthquake generated by the Wasatch Fault. The epicentral distance is 38 kms. This fault dips 60° to the southwest, the focal depth is approximately 10 kms, and the focal distance is approximately 32 kms.

A magnitude 7.0 earthquake generated by the West Mercur Fault with an epicentral distance of 6.4 kms and a focal depth 10 kms. This fault dips about 60° degrees to the southwest, the focal depth is approximately 20 kms, and the focal distance is about 15 kms. The epicenter is about 11 kms from the dam (32).

Of the two faults, the Wasatch Fault is clearly the most dangerous and the most likely to produce an earthquake in the next 1000 years.



NOTES

1. CONTOURS REPRODUCED FROM TOPOGRAPHIC MAP DATED AUGUST 1981 BY AAA ENGINEERING AND DRAFTING INC. SALT LAKE CITY, UTAH
2. SEE WOODWARD AND CLYDE "BASIC GEOTECHNICAL DATA REPORT RESERVATION CANYON DAM SITE, MERCUR GOLD PROJECT TOOELE COUNTY, UTAH" DATED JANUARY 15,1982 FOR BORE HOLE AND SEISMIC LINE DATA
3. SEE DAMES AND MOORE "SEEPAGE AND CONTAMINATION CONTROL EVALUATION, RESERVATION CANYON TAILINGS DISPOSAL AREA, MERCUR GOLD PROJECT, MERCUR, UTAH FOR GETTY MINERAL RESOURCES COMPANY," DATED NOVEMBER 1981

LEGEND

- SEISMIC LINE WOODWARD AND CLYDE
- ■ TEST PIT DAMES AND MOORE
- ● BORE HOLE DAMES AND MOORE
- ◐ BORE HOLE WOODWARD AND CLYDE
- MONITOR WELLS SEE DWG. 80-22-003

FIGURE 5.1

CLIENT MERCUR GOLD PROJECT
TOOELE COUNTY
GETTY MINING COMPANY
Salt Lake City, Utah

Davy McKee
DMC Engineers and Constructors
San Mateo, California

TITLE RESERVATION CANYON
TAILINGS DISPOSAL DAM
SUBSURFACE INVESTIGATION

DRAWING No. SC 2385A
80-22-009
SHEET 9 OF 17
REVISION B

DRAWING NO 80-22-009

REVISIONS	DESCRIPTION	BY	CH.	APPROVED	DATE
A	ISSUED FOR APPROVAL				3.2.1.82
B	ISSUED FOR BID				

	BY	DATE
DESIGNED		
DRAWN		
CHECKED		
APPROVED 1		1.25.82
APPROVED 2		
APPROVED 3		

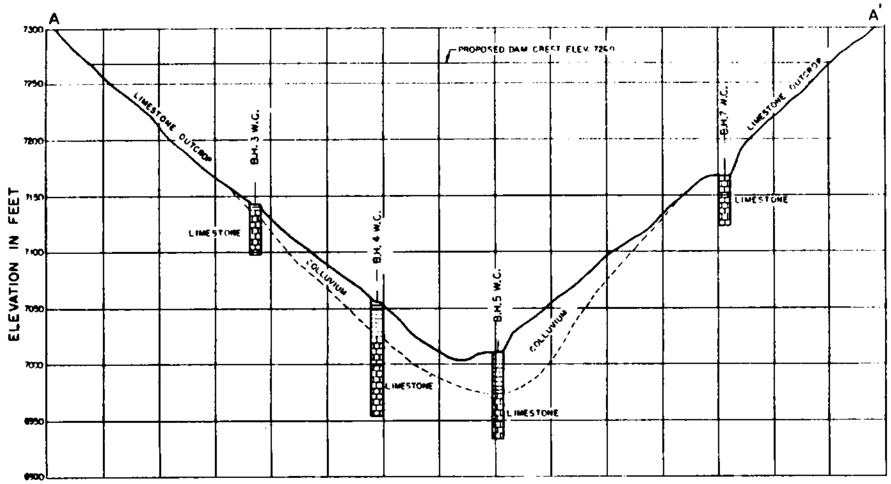
DATE TO	A	B
CLIENT	3/1	
FIELD		
CC-12	3/4	
MICROFILM		

5.0 FIELD INVESTIGATIONS

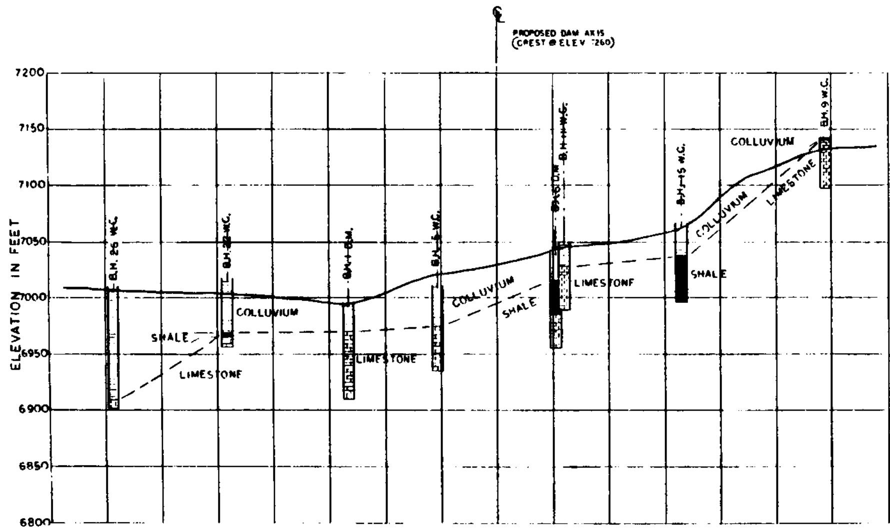
Field work at the site has been completed by Dames and Moore, Salt Lake City and Woodward-Clyde Consultants, San Francisco.

Work by Woodward-Clyde Consultants focused on the detailed geology of the site resulting in a number of reports describing the mechanical properties and distribution of rock and soil which are primarily for embankment design criteria. The Woodward-Clyde field program consisted of running 11 seimsmic profile lines, drilling 21 borings to depths of 41-197 feet, performing field soil-density tests, field permeability tests (one hole only), geologic mapping and test trench logging (three trenches) (32). See Figures 5.1 and 5.2.

Work by Dames and Moore focused on the potential for seepage and ground water contamination and resulted in a report describing this potential and proposed mitigative measures. In the course of their field program Dames and Moore drilled 10 exploration borings 69-100 deep. In addition, six shallow borings were completed in soil and alluviem for permeability tests. A series of 25 test pits were dug for logging and sampling. All of the deep exploratory borings were used for packer tests or casing inflow tests to assesss permeability of rock and soil (7). See Figures 5.1 and 5.2.



SECTION (A / 009)
SCALE: HORZ. 1"=100'



SECTION (B / 009)
SCALE: HORZ. 1"=100'

NOTES:

1.) THE SOIL-ROCK PROFILE HAS BEEN CONSTRUCTED FROM BORINGS PERFORMED AND REPORTED BY WOODWARD-CLYDE CONSULTANTS AND DAMES & MOORE AND FROM SEISMIC REFRACTION LINES PERFORMED BY WOODWARD-CLYDE CONSULTANTS.

2.) FOR APPROXIMATE BORING LOCATIONS SEE DRAWING 80-22-009

LEGEND:

B.H. 2 W.C. INDICATES: BORE HOLE NUMBER 2 BY WOODWARD-CLYDE CONSULTANTS

B.H. 2 D.M. INDICATES: BORE HOLE NUMBER 2 BY DAMES & MOORE

FIGURE 5.2

MERCUR GOLD PROJECT
TOOELE COUNTY
GETTY MINING COMPANY
Salt Lake City, Utah

Davy McKee
DMC Engineers and Constructors
San Mateo, California

RESERVATION CANYON
TAILINGS DISPOSAL DAM
SUBSURFACE PROFILES

5C2385A
80-22-010
SHEET 10 OF 17

80-22-009

5.0 FIELD INVESTIGATIONS (cont'd)

Although they strictly did not participate in field programs, Davy McKee Corporation engineers used data provided by Woodward-Clyde and Dames and Moore to indepoendently evaluate the same objectives of the field engineers.

Copies of the Woodword-Clyde, Dames and Moore, and Davy McKee technical reports are available from Getty Mining Company.

6.0 LABORATORY INVESTIGATIONS

Laboratory investigations used in developing the design of this tailings facility include, tailings liquor and solids chemistry tests, tailings settling tests, soil and tailings gradation, Atterberg limits, and permeability tests, soil pH, soil buffering capacity, soil cation exchange properties, soil mineralogical analyses and soil compaction tests.

Details of this work are availabe in a number of docments but Tables 6.1 through 6.8 have been extracted from these documents and reproduced in this application for convenience.

Note that Table 6.5 includes permeability data for tailings from an autoclave test process which will not be used in the mill. The oxide ore process tailings are representative of the proposed mill process.

TABLE 6.1

ANALYSES FROM COMPOSITE SAMPLE TREATED BY DIRECT CARBON-IN-LEACH (16)

	Feed Solids (Percentage)	Tails Solids (Percentage)	Tails Liquor (MG/1)
Hydroxide Alkalinity (1)			LT5
Phenol Alkalinity (1)			89
Total Alkalinity (1)			174
Aluminum			0.45
Antimony			0.44
Arsenic	0.26	0.26	3.04
Barium	0.7	0.65	1.4
Boron	0.05	0.05	0.07
Cadmium	LT 0.001	LT 0.001	0.018
Calcium	13.0	13.0	536
Carbonate (1)			168
Bicarbonate (1)			LT5
Organic Carbon	0.20	0.19	
Total Carbon	3.59	3.84	
Chloride	0.024	0.018	25
Copper	0.002	0.002	3.4
Total Cyanide			111
Free Cyanide			98.2
Cyanate			33
Thio Cyanate			650
Fluoride	0.18	0.16	2.0
Gold, FA	0.084 OZ/T	0.025 OZ/T	0.012
E.S.G. @ 20°			1.002
Iron	2.51	2.58	6.88
Lead	0.004	0.068	0.15
Magnesium	0.28	0.28	4.92
Manganese	0.050	0.051	0.048
Mercury	33 PPM	30 PPM	0.020
Nickel	0.005	0.006	0.50
pH			9.4
Phosphate	0.24	0.23	
Potassium	0.892	0.896	12.7

TABLE 6.1 (cont'd)

	Feed Solids (Percentage)	Tails Solids (Percentage)	Tails Liquor (MG/1)
Selenium	0.5 PPM	0.5 PPM	0.002
Silicon			2.6
Silica	47.0	48.3	
Silver	0.07 OZ/T	0.05 OZ/T	0.03
Sodium	0.055	0.055	1040
T.D.S.			6720
Sulfate			3410
Sulfide			LT 0.5
Sulfite			LT 0.5
Thallium	144.0 PPM	130.0 PPM	0.14
Zinc	0.016	0.013	11.7

Note: (1) Reported as Calcium Carbonate.
(2) Liquor was not recycled.
(3) Lead Nitrate was being added.

TABLE 6.2

GRADATION TEST RESULTS (7)

Location	Depth (ft)	Soil Classification	3/4"	#4	#10	#40	#200
TP 1	1-8	GM	64.0	40.5	33.4	28.0	21.5
TP 5	3	GM	70.2	54.8	48.8	43.5	31.6
TP 6	1-6	GM-ML	67.9	57.1	54.0	51.9	44.4
TP 8	4-6	GM	31.1	23.0	21.5	19.7	15.4
TP 9	3	GP-GM	60.9	34.6	20.0	13.4	9.3
TP 12	5-6	CL	94.1	89.9	86.3	77.2	71.2
TP 14	4-10	SC	96.4	79.2	65.3	44.1	32.8
TP-15	8	CL	91.6	85.9	84.1	78.9	76.7
TP-22	9-12	GP-GC	26.3	18.1	15.6	13.3	9.0
TP-24	5-7	GM	63.0	45.3	41.5	37.9	31.2
TP 25	3-4	GP-GM	44.4	21.4	18.6	16.7	13.2
Open Pit Area Near Surface		CL (Long Trail shale)	-	-	-	82.2	72.9
Pilot Tailing 1 (Autoclave Process)						100.0	88.8
Pilot Tailing 2 (Oxide Ore Process)						100.0	88.7

TABLE 6.3

SPECIFIC GRAVITY TEST RESULTS (7)

Location	Depth (ft)	Soil Type	Specific Gravity
TP14	4-10	CL	2.71
Open Pit Area	Near Surface	(Long Trail shale)	2.75
Pilot Tailing 1	-	ML	2.75

TABLE 6.4

ATTERBERG LIMITS TEST RESULTS (7)

Location	Depth (ft)	Liquid Limit	Plasticity Index	Soil Classification
TP 1	1-8	30.4	2.7	ML
TP 5	3	37.3	7.2	ML
TP 11	2.5	38.2	11.6	ML
TP 14	4-10	32.9	13.9	CL
Ope Pit Area	Near Surface	34.6	14.6	CL (Long Trail shale)
Pilot Tailing 1		21.4	1.7	ML

TABLE 6.5

LABORATORY PERMEABILITY TEST RESULTS (7)

Location	Depth (ft)	Soil Classification	Dry Density (lb/ft^2)	Confining Pressure (lb/ft^2)	Type Test*	Permeability (ft/year) with Water	Permeability (ft/year) with Basic Solution
TP 5	3	GM	86.0***	1,500	f	5.	3.
TP 14	4-10	CL	100.0***	1,500	f	12.	2.5
Boring 3	15.5	CL	95.3	1,500	f	1.	-
Boring 3	25.5	CL	93.5	3,000	f	10.	-
Open Pit Area	Near Surface	CL**	116.0	2,000	f	0.15	-
Open Pit Area	Near Surface	CL**	115.9	4,000	f	0.1	-
Open Pit Area	Near Surface	CL**	104.4	1,500	c	250	590
Pilot Tailings 1	(Autoclave Process)	ML	96.9	100	f	1.1	-
Pilot Tailings 1	(Autoclave Process)	ML	101.8	500	f	1.2	-
Pilot Tailings 1	(Autoclave Process)	ML	100.9	1,000	f	1.1	-
Pilot Tailings 1	(Autoclave Process)	ML	98.0	1,500	f	1.3	1.3
Pilot Tailings 2	(Oxide Ore Process)	ML	94.2	100	f	1.3	-
Pilot Tailings 2	(Oxide Ore Process)	ML	101.4	500	f	0.7	-
Pilot Tailings 2	(Oxide Ore Process)	ML	102.0	1,000	f	0.8	-
Pilot Tailings 2	(Oxide Ore Process)	ML	101.5	1,500	f	0.8	-

* f refers to falling head permeameter; c refers to constant head permeameter
** Long Trail shale
*** Recompacted Samples

TABLE 6.6

CLAY MINERALOGY TEST RESULTS (7)
(Mineral Content by Percent Weight)

Mineral	Test Pit 3 at 7 feet	Test Pit 7 at 1 foot	Test Pit 14 at 4-10 feet	Test Pit 25 at 3-4 feet	Long Trail shale	Tailings
Quartz	59.95	51.41	51.79	64.48	18.19	31.81
Montmorillonite	2.00	3.73	9.45	13.10		0.92
Limanite/Hematite	0.90	3.28	1.21	1.68	5.85	2.11
Rutite	0.38	0.60	0.30	0.47	0.97	0.38
Calcite	10.19	2.33	22.54		4.10	33.51
Illite	13.61	10.61	8.96	4.92	4.96	10.84
Microline	2.62	6.33	0.82	8.30	2.14	
Albite	7.00	9.10	1.22	1.13	5.93	1.09
Pyrite	0.13	0.08	0.09	0.05	0.04	
Dolomite		2.45	0.52			0.03
Kaolinite	0.36	9.47	2.96	3.84	39.24	9.79
Chlorite	2.74	0.50		1.92	0.94	
Nontronite					17.49	
Anhydrite						9.48
Compound						
SiO_2	74.43	72.15	64.76	82.61	53.48	43.16
Al_2O_3	6.33	10.10	5.87	7.75	20.73	7.04
Fe_2O_3	2.22	3.86	2.11	2.72	10.89	3.06
TiO_2	0.373	0.583	0.304	0.462	0.966	0.379
CaO	5.73	2.20	13.29	0.689	2.86	22.74
MgO	1.20	1.24	0.892	1.08	0.460	0.151
K_2	1.64	1.98	0.945	1.83	0.804	0.961
Na_2	0.78	1.01	0.167	0.168	0.978	0.125
SO_3	0.168	0.106	0.122	0.0637	0.0589	5.58
CO_2	4.41	2.15	10.15	0.00	1.80	14.76
H_2O+	1.16	2.25	1.36	1.74	7.03	2.06
H_2O-	2.36	0.979	0.849	1.64	2.90	0.400
Organics	1.66	2.12	0.0756	0.839	0.00	0.00

TABLE 6.7

SOIL GEOCHEMICAL TEST RESULTS (7)

Location	Depth (ft)	Soil pH	Exchangeable Cations (meq/100g) Ca	Mg	Na	K	H	Cation Exchange Capacity (Meq/100g)	Calcium Carbonate Equivalent (%)	Gradation Sand	Silt	Clay
TP 5	3	7.5	17.40	1.30	0.10	0.70	0.00	18.7	5.6	45	37	18
TP 7	1	7.5	18.10	2.50	0.10	1.40	0.00	22.1	2.5	16	66	18
TP 9	12	7.7	13.40	1.10	0.10	0.80	0.00	16.2	6.8	64	22	14
TP 12	5-6	8.0	21.20	2.40	0.10	0.30	0.00	26.2	8.9	25	43	32
TP 13	3-5	8.0	12.70	0.80	0.10	0.30	0.00	13.9	11.5	34	46	20
TP 14	4-10	8.0	15.90	6.40	0.30	0.40	0.00	24.7	5.7	29	39	32
TP 16	3-8	7.4	15.90	2.70	0.10	0.70	0.00	20.9	1.4	43	31	26
TP 19	2-5	8.0	17.70	2.30	0.00	0.90	0.00	20.1	4.5	26	44	30
TP 23	5-7	8.0	14.00	2.50	0.00	1.00	0.00	16.6	6.0	46	36	18
TP 25	3-4	7.5	14.10	3.20	0.10	0.30	0.00	17.4	0.8	35	39	26

Tests performed in accordance with U.S.D.A. Handbook 60

TABLE 6.8

BUFFERING CAPACITY TEST RESULTS (7)

Sample Location and Depth, and dry weight of sample:	TP 3 at 7 ft (60.139 gm)		TP 7 at 1 ft (60.214 gm)		TP 14 at 4 to 10 ft (61.518 gm)	
Cummulative Volume of Liquor added (ml)	ml of liquor added per gm soil	resulting pH of soil paste	ml of liquor added per gm soil	resulting pH of soil paste	ml of liquor added per gm soil	resulting pH of soil paste
0	.0000	7.2	.0000	7.0	.0000	7.3
5	.0831	7.4	.0830	7.0	.0813	7.3
10	.1662	7.5	.1660	7.4	.1626	7.7
15	.2494	7.6	.2491	7.4	.2438	7.7
20	.3326	7.7	.3321	7.5	.3251	7.8
25	.4157	7.7	.4152	7.5	.4064	7.8
30	.4988	7.7	.4982	7.5	.4877	7.9
35	.5819	7.8	.5813	7.6	.5689	8.0
40	.6615	7.9	.6643	7.6	.6502	8.1
45	.7483	7.9	.7473	7.8	.7314	8.1
50	.8314	7.9	.8304	7.9	.8128	8.5
55	.9146	8.0	.9134	7.9	.8940	8.7
60	1.080	8.6	.9964	8.0	.9753	8.8
65	1.164	8.7	1.079	8.2		
70	1.330	8.7	1.162	8.3		
75	1.496	8.7	1.328	8.5		
80			1.494	8.8		
85						
90						

TABLE 6.8 (cont'd)

Sample Location and Depth, and dry weight of sample:

	TP 19 at 2-5 ft (60.147 gm)		TP 25 at 3 to 4 ft (60.177 gm)	
Cummulative Volume of Liquor added (ml)	ml of liquor added per gm soil	resulting pH of soil paste	ml of liquor added per gm soil	resulting pH of soil paste
0	.0000	7.4	.0000	7.0
5	.0831	7.4	.0831	7.0
10	.1663	7.6	.1662	7.1
15	.2494	7.7	.2493	7.2
20	.3325	7.7	.3324	7.2
25	.4156	7.7	.4154	7.2
30	.4987	7.8	.4985	7.4
35	.5819	7.9	.5816	7.5
40	.6650	7.9	.6647	7.6
45	.7482	8.0	.7478	7.6
50	.8313	8.0	.8308	7.8
55	.9144	8.1	.9139	7.8
60	.9976	8.3	.9971	7.9
65	1.080	8.4	1.080	8.0
70	1.163	8.4	1.163	8.2
75	1.330	8.5	1.329	8.3
80	1.496	8.6	1.495	8.5
85	1.662	8.7	1.661	8.7
90	1.828	8.7	1.827	8.7

7.0 HYDROLOGY

7.1 General

The general area is mountainous terrain with slopes ranging from 5 to 50 percent. Vegetation native to the area is pinyon pine, juniper, oakbrush, big sagebrush, black greasewood and some aspen. The principal uses are range and wildlife habitat.

The elevation of the dam site is above 7000 feet, hence much of the annual precipitation is in the form of snow. The annual precipitation is approximately 17.4 inches(30), and the annual evaporation is about 42°inches.(7). In general, evaporation is higher than precipitation at all times of the year except in December and January.

7.2 Surface Water

The total drainage area of Reservation Canyon upstream of the proposed dam is relatively small, consisting of approximately 788 acres. Reservation Canyon heads from the Oquirrh Mountains and joins Meadow Canyon from the northwest as a tributary to Mercur Creek. Reservation Canyon is an ephemeral stream which flows in response to thunderstorm and spring snowmelt. The confluence of these two natural drainage channels is situated just north of the plant site and mine area.

Because of the steep topography and relatively short time lag, runoff from flash floods requires special attention to the peak flow used to design any conveyance structure.

7.3 Ground Water

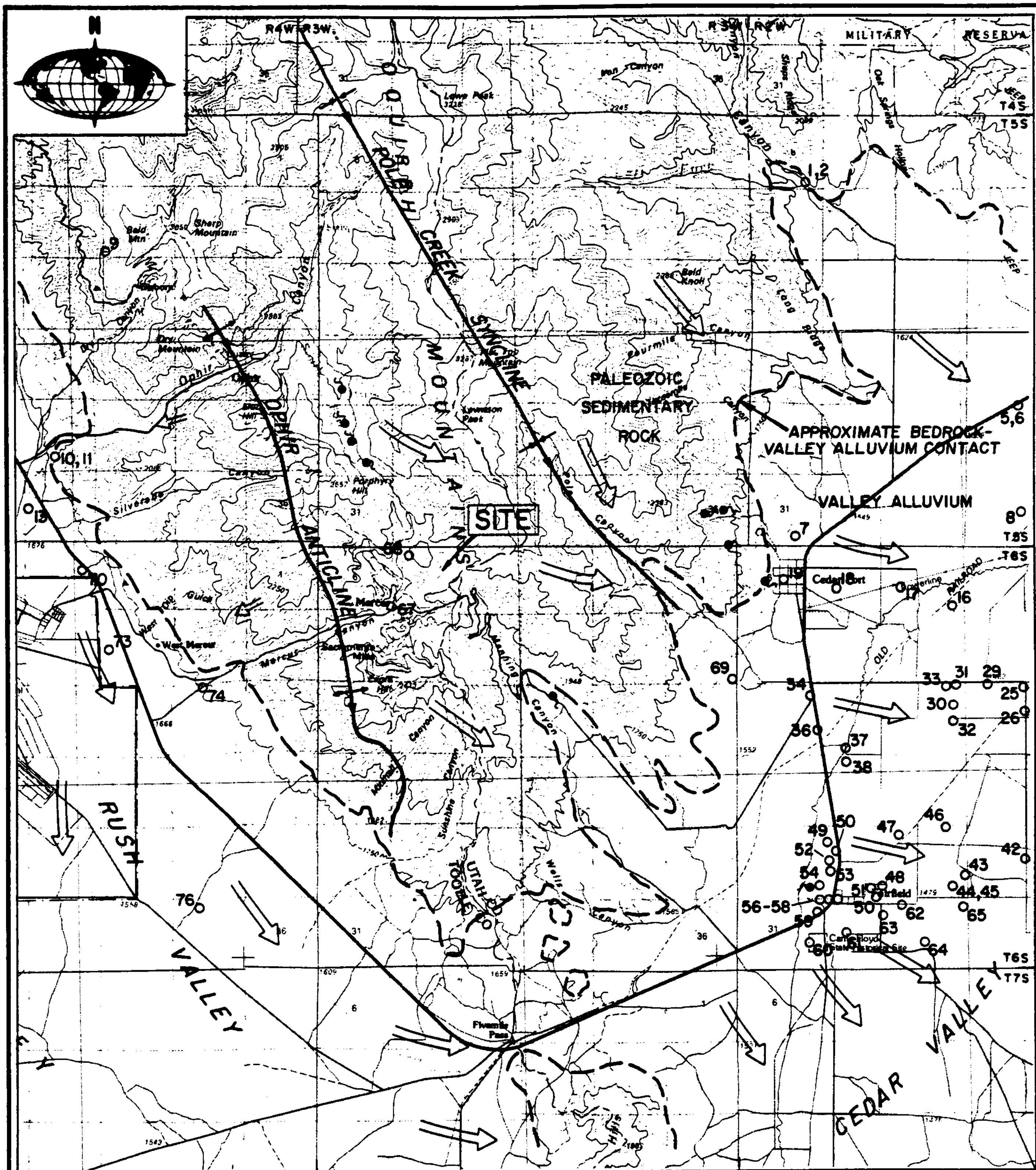
Drilling and other subsurface exploration activities at the site reveal that no shallow ground water aquifer is encountered in the area. A few springs occur at higher elevation above 7300 and discharge in direct response to snow melt and storms as interflow. The major aquifer is believed to occur at least 700 feet below ground surface.

The following ground water description is reproduced from the Dames & Moore report (7).

The primary aquifers in the region are the unconsolidated deposits located in Cedar and Rush Valleys. Bedrock of the mountainous area is virtually unused as an aquifer, but is important in that it transits ground water recharge to the valleys through fractures and fissures. Paleozoic sedimentary rocks have low primary permeability, but repeated fracturing by folding and faulting has caused the development of secondary permeability. Although true karstic conditions do not occur in the limestones of the area, fractures and joints in carbonate rock have been enlarged by solutioning as water moves through them. High ground water yields have been reported from a few springs and wells, and in some mine openings in the region. The relatively impervious beds of the Manning Canyon shale control the locations of many springs, such as the spring in Manning Canyon, and control the flow of water in the subsurface. Figures 7.1 shows major hydrogeologic features of the area.

Unconsolidated rock in Rush Valley is primarily fine-grained with the coarsest materials in alluvial fan deposits near the mountains. Ground water is believed to be unconfined along the mountain front and upper reaches of alluvial fan deposits and is confined in the valley low lands. Unconsolidated alluvial deposits along the base of the Oquirrh Mountains in Rush Valley yield up to 350 gallons per minute (gpm) to indiviudal wells along the alluvial apron. Several wells in the far north-central Rush Valley yield 650 to 970 gpm. Elsewhere in Rush Valley well yields rarely are greater than 300 gpm.

In unconsolidated deposits in Cedar Valley groundwater is under both unconfined and confined conditions. Water table conditions predominate around the edges of the basin, although confined conditions are present in the valley fill alluvial fan system opposite the drainages of Pole and Manning Canyon. The artesian aquifers between Cedar Fort and



KEY

O9 WELL LOCATION AND NUMBER (SEE TABLE 1)

SPRING LOCATION (SEE TABLE 2)

CONTACT OF BEDROCK AND VALLEY ALLUVIUM

GROUND WATER FLOW DIRECTION

BASE MAP ELEVATIONS ARE IN METERS, CONTOUR INTERVAL — 50 METERS

REGIONAL HYDROGEOLOGIC FEATURES

SCALE IN MILES

1 0 1 2

REFERENCE
U.S.G.S. 100,000 METRIC TOPOGRAPHIC MAP ENTITLED "RUSH VALLEY, UTAH" 1979.

FIGURE 7.1

DAMES & MOORE

Fairfield have had the greatest.development as sources of ground water in Cedar Valley. Near the town of Fairfield, wells flow from the artesian aquifer and yields of up to 3,600 gpm have been reported.

A well and spring inventory has been prepared from the records of the Utah State Engineer and other publications (9, 14). All wells of record within six miles of the site are included on Table 7.1 and are plotted on Figure 7.1. Information on selected springs is summarized on Table 7.2. Use of well water is mostly for irrigation with stockwatering and domestic consumption a lesser, but important use.. Other than the well owned by Getty Minerals, about 1/2 mile southwest of the site, there are no downgradient wells within four miles of the proposed tailings reservoir. A spring is located in Manning Canyon about 2 1/2 miles southeast of the site. There are several springs in Ophir Canyon northwest of the site, but these are hydrologically upgradient. A well (No. 68, Table 7.1) is recorded as located on the hill northwest of the tailings area. This record is apparently incorrect since no well is known to exist there.

The principal recharge area for Cedar Valley and Rush Valley is in the Oquirrh Mountains where snowmelt percolates directly in fractures and fissures of the rock. A minor

Table 7.1

WELL INVENTORY (7)

Well Number	Owner or Name	Appl Number	Location	Year Drilled	Use	Yield (gpm)	Draw Down	Type	Diam (in)	Well Depth
1	Cedar Fort IRR	A-7119	C-5-2 7AAB-1	1975	I			B	10	416
2	Cedar Fort IRR	A-22846	C-5-2 7AAB-1	1973		20	2	B	16	83
3	US Geol Survey		C-5-2 24AAB-1	1966	U			B	1	155
4	Adkins Patters	A-43344	C-5-2 25BBB-1	1977	H I S	5	8	C	8	506
5	Smith	A-17743	C-5-2 26BBB-2	1960	S			C	8	448
6	State of Utah		C-5-2 26BBB-1	1916	S	18		B	8	448
7	Cook	A-34441	C-5-2 31DCD-1	1963	I	12	0	C	8	325
8	Woodhouse	-2900	C-5-2 34DAA-1	1943		3		Z	6	280
9	Nielson	A-53398	C-5-4 10CCC-1	1980	H	50	30	B	6	380
10	Snyder Mines	A-12696	C-5-4 28CDB-1	1937	U	178	15	Z	12	90
11	Snyder Mines	A-12696	C-5-4 28CDB-2	1937	U	146	15	Z	12	86
12	Xruletz	A-47714	C-5-4 31DAA-1	1977	H I S	59	4	C	6	101
13	Russell	A-47071	C-5-4 32DAA-1	1976	H S	0	0	C	6	344
14	Hisley	A-25172	C-5-4 33CCA-1	1958				B		430
15	US Geol Survey		C-6-2 1ACC-1	1966	U			B	1	300
16	Davis	A-40140	C-6-2 3CCC-1	1970	S	20	0	C	8	300
17	Cedar Fort IRR	A-97119	C-6-2 4CAC-1	1974	I	250		H	8	445
18	US Geol Survey		C-6-2 5CAD-1	1930	U			B	4	105
19	Berry	A-34700	C-6-2 6DBA-1	1962	H	25	0	C	6	200
20	Smith	A-41498	C-6-2 9BAA-1	1975	S	150	75	C	10	225
21	Coop Security	A-25280	C-6-2 13CAA-1	1962	I			C	10	526
22	LDS Church	A-25333	C-6-2 13DDA-1	1954	I			B	20	1014
23	Coop Security		C-6-2 14ABA-1	1954	U	90		B	12	1258
24	Coop Security		C-6-2 14ACA-1	1954	U			B	12	1014
25	Coop Security	A-32714	C-6-2 14BBB-1	1962	I			B	10	485

Table 7.1 (cont'd)

Well Number	Owner or Name	Water-Bearing-Zone Char	Depth	Thick	Water Level	Month-Yr Measured
1	Cedar Fort IRR	JFL	80	274	70	8-75
2	Cedar Fort IRR	JFL				
3	US Geol Survey				127	6-66
4	Adkins Patters	GP	300	200	290	3-77
5	Smith	G	36		361	6-60
6	State of Utah				361	6-60
7	Cook	G	300	25	300	4-63
8	Woodhouse	S	250	30	350	4-43
9	Nielson	SG	360	20	140	1-80
10	Snyder Mines	GJF	67	19	62	5-37
11	Snyder Mines	DJF	71	9	62	5-37
12	Xruletz	GP	35	10	35	5-77
13	Russell			0	0	12-76
14	Hisley					
15	US Geol Survey				175	3-66
16	Davis	G	195	25	164	9-70
17	Cedar Fort IRR	G	83		80	11-74
18	US Geol Survey				83	2-66
19	Berry	GS			158	12-62
20	Smith	GS	80	10	72	12-21
21	Coop Security				120	5-62
22	LDS Church					
23	Coop Security				122	3-66
24	Coop Security				110	2-66
25	Coop Security					

Table 7.1 (cont'd)

Well Number	Owner or Name	Appl Number	Location	Year Drilled	Use	Yield (gpm)	Draw Down	Type	Diam (in)	Well Depth
26	LDS Church	A-22714	C-6-2 14BCC-1	1954	I			B	16	1007
27	LDS Church	A-22711	C-6-2 14CAC-1	1951	I			B		1250
28	Coop Security	A-4308	C-6-2 14DBB-1	1964	I			6	20	810
29	Coop Security	A-29875	C-6-2 15ABB-1	1961	I	75	0	6	16	2103
30	Coop Security	A-29875	C-6-2 15BCB-1	1959	I			6	16	955
31	Coop Security		C-6-2 15BBB-1	1957	I	515	134	B	16	835
32	Coop Security	A-29875	C-6-2 15CBB-1	1957	I			C	16	455
33	Smith	A-8552	C-6-2 16AAA-1	1951				B		505
34	White	A-22883	C-6-2 17BBC-1	1971	H	1725	32	6	16	466
35	Coop Security		C-6-2 17DCC-1	1961	I	2000	67	B	16	600
36	White	A-34575	C-6-2 17CBD-1	1962	H S	100		C	8	147
37	White	A-22826	C-6-2 17DCC-2	1962	I	3600	97	C	16	595
38	Smith	A-22928	C-6-2 20ABB-1	1961	I	2400	67	C	16	600
39	Penrod	A-46616	C-6-2 24BDD-1	1977	H	12	1	C	6	193
40	Coop Security		C-6-2 25CBC-1		S			B		
41	Coop Security	A-5480	C-6-2 25CCC-1	1970	I	0		C	16	500
42	Coop Security	A-25280	C-6-2 26CBB-1	1962	I			C	18	505
43	Meinzer	A-10548	C-6-2 27CCA-1	1953		25		B	6	80
44	US Geol Survey		C-6-2 27CCC-1	1966	U			B	1	505
45	US Geol Survey		C-6-2 27CCC-2	1966	U			B	1	100
46	Meinzer	A-10550	C-6-2 28AAA-1	1953		25	5	B	6	80
47	S. D. Nichols		C-6-2 28BAC-1	1953	U			B	6	80
48	Anderson	A-47396	C-6-2 28CCC-1	1977	H I S	17	22	C	6	300
49	White		C-6-2 29BDB-1	1960		125	200	C	16	654
50	E. R. Carson		C-6-2 29BDD-1		S	108		B	3	150

Table 7.1 (cont'd)

Well Number	Owner or Name	Water-Bearing-Zone Char	Depth	Thick	Water Level	Month-Yr Measured
26	LDS Church	PS	98	900		
27	LDS Church	SG	950	100	80	5-51
28	Coop Security	S	120	430	102	3-64
29	Coop Security	PG	222		200	10-60
30	Coop Security	PG	278		180	7-59
31	Coop Security				119	2-66
32	Coop Security	P	190	220	77	8-57
33	Smith	P	50		45	5-51
34	White	PG	185		164	5-71
35	Coop Security				21	3-66
36	White	G	125	22	96	9-62
37	White	P	170			
38	Smith	PG	150		28	12-61
39	Penrod	G	189	3	140	4-77
40	Coop Security				69	3-66
41	Coop Security			0		
42	Coop Security	PSG	210	290	48	7-62
43	Meinzer	P	35	45	35	9-53
44	US Geol Survey				28	4-66
45	US Geol Survey				25	4-66
46	Meinzerr	P	15		15	9-53
47	S. D. Nichols				20	3-66
48	Anderson	SG	154	26	20	11-77
49	White	SG	267		14	1-68
50	E. R. Carson				13	1-66

Table 7.1 (cont'd)

Well Number	Owner or Name	Appl Number	Location	Year Drilled	Use	Yield (gpm)	Draw Down	Type	Diam (in)	Well Depth
51	McCauley	A-97395	C-6-2 29DDD-1	1977	H I S	22	12	C	6	281
52	Meinzer	A-10552	C-6-2 29CAB-1	1953				B	8	220
53	L. N. Meinzer		C-6-2 29CAC-1		S	1		B	4	350
54	E. R. Carson		C-6-2 29CCC-1		I S	1.7		B	3	189
55	McKinney	A-47123	C-6-2 32AAA-1	1973	H I S	18	30	C	6	196
56	White	A-22826	C-6-2 32BBA-1	1964	I	50	145	C	16	613
57	UT State Parks	A-33658	C-6-2 32BAA-1	1962	I	20	2	B	14	30
58	Crossman	A-22063	C-6-2 32BAB-1	1967	H	10	7	C	6	210
59	M. K. White		C-6-2 32BBD-1	1964	I	750	145	B	16	613
60	UT State Parks		C-6-2 32CBC-1		I			B	4	64
61	Meinzer	A-10546	C-6-2 32DBB-1	1953		50		B	8	365
62	Clover	A-7539	C-6-2 33BAC-1	1974	H I S			C	12	280
63	Rulon Carson		C-6-2 33BCB-1		H I	1		B	2	525
64	Stake		C-6-2 33DBD-1	1967	H	50	24	C	8	302
65	Meinzer	A-10549	C-6-2 34BBD-1	1953		25		B	6	275
66	Coop Security		C-6-2 36BBC-1	1970	I	0		C	16	500
67	Getty Minerals		C-6-3 5CCC-1	1980	N	40		B	5	865
68	Lewiston Peat	C-11815	C-6-3 5BAC-1		S			D		65
69	Wofford	A-47377	C-6-3 12DDD-1	1981	H I S			B	6	547
70	Getty Minerals		C-6-4 4ACD-1	1981		215	25		6	1696
71	US Army Well 1	A-15128	C-6-4 5BDB-1	1942	H	340	5.5	C	12	405
72	US Army Well 2	A-15128	C-6-4 5BDD-1	1942	H	364	7	C	12	428
73	Getty Minerals		C-6-4 10CBB-1	1981		149	169		6	1920
74	Getty Minerals		C-6-4 14BA-1	1980	U	85	7	B	5	735
75	L. A. Stookey	A-35140	C-6-4 31ACB-1	1963	S	308	0	C	6	50
76	US Land Mgmt	A-26409	C-6-4 35BAC-1	1954	S	18	5	C	6	365

Table 7.1 (cont'd)

Well Number	Owner or Name	Water-Bearing-Zone Char	Depth	Thick	Water Level	Month-Yr Measured
51	McCauley	SG	262	19	6	5-77
52	Meinzer	S	220		12	9-53
53	L. N. Meinzer				1	4-66
54	E. R. Carson				3	3-66
55	McKinney	GS			10	4-77
56	White	PG	490			3-64
57	UT State Parks	PSG	8	22	8	3-62
58	Crossman	PG	191	25		
59	M. K. White					3-64
60	UT State Parks					
61	Meinzer	P	15	40	15	9-53
62	Clover	PS	45	70	9	9-74
63	Rulon Carson				11	4-66
64	Stake	PS	235	40	30	9-67
65	Meinzer	P	30		30	9-53
66	Coop Security	PS		0		
67	Getty Minerals	L	485	380	485	3-81
68	Lewiston Peat					
69	Wofford	L	487		487	4-81
70	Getty Minerals	SG	360		477	7-81
71	US Army Well 1	G	290	114	284	12-51
72	US Army Well 2	SGC	312	116	287	9-42
73	Getty Minerals	SG	390		390	8-81
74	Getty Minerals	SG			205	12-80
75	L. A. Stookey	SG	25	20	27.6	3-67
76	US Land Mgmt	PS	210	155	148	3-67

Table 7.1 (cont'd)

Key:

Well Number	- Sequential Number used to reference well.
Owner or Name	- Owner of record on well completion report.
Appl Number	- State Engineer's application number for well.
Location	- Utah State location designation system - see explanation on following page.
Year Drilled	- Year well was drilled.
Use	- Reported Water Use: D = Domestic I = Irrigation, M = Mining N = Industrial P = Municipal S = Stock Watering T = Test Well U = Unused
Yield	- Reported test yield
Drawdown	- Reported test drawdown in feet for reported test yield
Type	- Well drilling method: C = cable tool R = Rotary D = Dug J = jetted
Diam	- Reported minimum cased well diameter in inches.
Well depth	- Maximum well depth in feet.
Water Bearing Zone Char	- Lithologic character of the water bearing Zone: B = Boulders C = Clay, G = Gravel J = Fractured Shale, L = Limestone S = Sand T = sandstone
Water Bearing Zone Interval	- Uppermost and lowermost depth of perforations in well; may contain unperforated section within this zone
Water Level	- Reported water level depth in feet
Month-year measured	- Date of water level measurement

Table 7.2

RECORDS OF SELECTED SPRINGS (7)

Key

Location: Utah State number system (see Hood and others, 1969)
Use of water: D - domestic, I - irrigation, S - stock
Dependability: G - good, F - fair
Yield (gpm): e - estimated, m - measured
Remarks and other data available: C - chemical analysis (Table 4), H - hydrograph (fig. 5), K-specific conductance (Table 4)
Source of data: Feltis (1967) and Hood and others (1969)

Location	Owner or Name	Formation or Type of Rock	Nature of Openings	Use of Water	Temperature (°F)	Dependability
(C-5-3) 4cdc		Oquirrh Formation	Joins and solution channels in limestone	S	44	-
4dcd		Alluvium	Seep area in canyon fill	S	42	G
(C-5-3) 30dbb-S1	U.S. BLM	Paleozoic Limestone	Joints and solution channels	S	47	-
30dcd-S1	U.S. BLM	Manning Canyon Shale	do	S	45	-
36cba	Cedar Fort Irrigation Co.	Oquirrh Formation	Joints and solution channels in limestone	I,S	46	G

Table 7.2 (cont'd)

Key

Location: Utah State number system (see Hood and others, 1969)
Use of water: D - domestic, I - irrigation, S - stock
Dependability: G - good, F - fair
Yield (gpm): e - estimated, m - measured
Remarks and other data available: C - chemical analysis (Table 4), H - hydrograph (fig. 5), K-specific conductance (Table 4)
Source of data: Feltis (1967) and Hood and others (1969)

Location	Owner or Name	Improvements	Yield (gmp) and date of measurement	Deposits	Remarks and other data available
(C-5-3) 4cdc		None	10e 11-2-65	do	K
4dcd		Pipeline and trough	5m 11-2-65	do	Water piped about half a mile to water trough. K
(C-5-3) 30dbb-S1	U.S. BLM		<5e 9-25-64	-	C
30dcd-S1	U.S. BLM	trough	1.25m 9-25-64	-	Flows through trough. C
36cba	Cedar Fort Irrigation Co.	None	300e 7-22-65	Tufa	C

Table 7.2 (cont'd)

<u>Key</u>

Location: Utah State number system (see Hood and others, 1969)
Use of water: D - domestic, I - irrigation, S - stock
Dependability: G - good, F - fair
Yield (gpm): e - estimated, m - measured
Remarks and other data available: C - chemical analysis
(Table 4), H - hydrograph (fig. 5), K-specific conductance (Table 4)
Source of data: Feltis (1967) and Hood and others (1969)

Location	Owner or Name	Formation or Type of Rock	Nature of Openings	Use of Water	Temperature (°F)	Dependability
(C-6-2) 4cdc	do	Alluvium overlying the Oquirrh Formation	-	D,I,S	50	G
29ccc	Fairfield Spring	Alluvium fan	Large seep and spring area at toe of alluvial fan	D,I,S,	52	G
(C-6-3) aad	Cedar Fort Irrgation Co.	Oquirrh Formation	Joints and solution channels in limstone	D.I.S	47	G
15bad		do		S	52	F

Table 7.2 (cont'd)

Key

Location: Utah State number system (see Hood and others, 1969)
Use of water: D - domestic, I - irrigation, S - stock
Dependability: G - good, F - fair
Yield (gpm): e - estimated, m - measured
Remarks and other data available: C - chemical analysis (Table 4), H - hydrograph (fig. 5), K-specific conductance (Table 4)
Source of data: Feltis (1967) and Hood and others (1969)

Location	Owner or Name	Improvements	Yield (gmp) and date of measurement	Deposits	Remakrs and other data available
(C-6-2) 6cad	do	Headhouse and pipeline	>124m 7-22-65	None	C
29ccc	Fairfield Spring	Headhouse, pipeline, and diversion system	2,070m 7-3-11-66	do	C, H
(C-6-3) aad	Cedar Fort Irrigation Co.	tunnel and pipeline	>88m 7-22-65	Tufa	C
15bad		None	7m 6-21-65	None	C

amount of recharge enters alluvial deposits in the mountains, in alluvial fans on the front and along valley streams. Although the site is within the surface drainage tributary to Rush Valley, it is within an area believed to recharge ground water of Cedar Valley because of the geologic structure (9,14). The recharge area to Cedar Valley extends east from the Ophir Anticline. See Figure 7.1.

Ground water movement in the mountainous area in the vicinity of the site is not well known and is complicated due to the complex nature of bedding and fracturing. Overall ground water movement is believed to be controlled by major geologic structure and topographic features which control recharge locations. Overall movement would be downdip northeasterly toward the southeast-plunging Pole Canyon Syncline, and then southeasterly toward Cedar Valley in response to topographic features. Ground water movement within the alluvial sediments of Cedar Valley is relatively well understood and is to the southeast. Groundwater in alluvial sediments in Rush Valley near the mouth of Mercur Canyon moves southerly and southeasterly toward Fivemile Pass and ultimately moves eastward into Cedar Valley through fractured bedrock.

7.0 HYDROLOGY (cont'd)

Ground water is discharged by springs, by wells, by evapotranspiration and by subsurface outflow from the ground water basins. Several springs near Fairfield discharge water derived from the Oquirrh Mountains. Fairfield Spring is the largest and generally discharges 1300 to 2200 gallons per minute. A small unnamed spring is located in Manning Canyon about 2 1/2 miles southeast of the site.

Ground waters in the northwestern part of Cedar Valley and northeastern Rush Valley are generally of the calcium bicarbonate type and of good quality with total dissolved solids usually less than 400 milligrams per liter (mg/L).

Little data is available on quality in the mountains, but it is likely good. Localized poor ground water quality conditions are possible along Mercur Canyon and Manning Canyon due to extensive past mining and milling activities (5).

7.4 Hydrologic Design of Tailings Impoundment

The impoundment is designed to store 1/2 of the Probable Maximum Flood (PMF) volume, in addition to the tailings volume deposited during the 12 year operation of the mill.

7.0 HYDROLOGY (cont'd)

The PMF is defined as the hypothetical flood event that would result from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible at a particular location.

7.5 Runoff Volume

The total drainage area (including the tailings impoundment) is approximately 788 acres (1.2 sq.mi.). The watershed location and drainage boundary are shown on Figure 1.2. The drainage basin is uniformly covered by woodland type of vegetation with occasional barren spots. Assuming hydrologic soil of B type and an AMC II condition, an average curve number for the land portion of the drainage area is chosen to be 60. Since the impoundment area of approximately 74.5 acres (0.12 sq.mi.) comprises about 10 percent of the entire drainage area, the inflow volume will be computed separately for the runoff from the land portion and the precipitation falling directly on the pond surface.

The excess runoff from the PMP 24-hour storm is obtained based on the curve number which is a measure of the infiltration potential of the drainage area. The volume of PMF from the land portion is found to be 13.7 million ft^3. The volume of PMF accumulated in the pond from rainfall falling directly on the pond is 2.8 million ft^3.

7.0 HYDROLOGY (cont'd)

The 1/2 PMF volume storage required in the impoundment is half the sum of the excess runoff for the land and pond portion of the drainage basin which is 16.6 million ft^3. The computation of the runoff volume is presented in Table 7.3. A freeboard of at least 2.40 feet is required based on a surface area of 3.5 million ft^2 at elevation 7260 ft. above mean sea level. See Table 7.4. The inflow volumes for the 10-year, 100-year storm and 1/2 PMF are shown in Table 7.5.

Table 7.3

INFLOW VOLUMES FOR STORMS OF DIFFERENT RECURRENCE INTERVALS

	Rainfall Depth (R) (in.)	Q (in.)	Runoff Volume From Land Portion of Drainage Basin $\frac{AQ}{12}$ (ft^3)	Rainfall Volume Falling Directly on Impoundment $\frac{BR}{12}$ (ft^3)	Total Inflow Volumes (ft^3)
10 yr	1.78	0.028	72,520	481,374	553,894
100 yr	4.40	0.970	2,512,305	1,189,914	3,702,219
PMF	10.5	5.31	13,752,927	2,839,568	16,592,495
1/2 PMF					8,296,248

Runoff Volume Computation

$$S = \frac{1000}{CN} - 10 \qquad (1)$$

where S = maximum potential diference between direct runoff and storm rainfall (inches)

CN = curve number

$$Q = \frac{(P-0.2S)^2}{P + 0.8xS} \qquad (2)$$

where Q = cumulative direct runoff (inches)

P = cumulative rainfall (inches)

Land area of drainage basin (A) = 31,080,060 ft^2

Impondment area (B) = 3,245,220 ft^2

Curve number (CN) = 60

from equation (1)

S = 6.67

Table 7.4

FREEBOARD REQUIREMENTS

Stage	Pool Elevation	Surface Area (A) x 10 6 (ft^2)	Freeboard Required to Store 1/2 PMF = 8,296,248 (ft) / A
1	7165	1.18	7.03
2	7215	2.32	3.58
3	7260	3.50	2.37

Table 7.5

INFLOW VOLUMES FOR DIFFERENT 24-HOUR STORMS

Recurrence Interval	Total Volume to Impoundment x 10 6 (ft^3)
10 - year	0.554
100 - year	3.70
1/2 - PMF	8.30

8.0 SEEPAGE

This section will first develop a model to determine the seepage rate from the tailings pond and the effect of the tailings on that rate. The seepage zone will be determined as well as its initial chemical composition. We will discuss the effect of several factors which will affect the final chemical composition of the seepage. A comparison will be made with regard to various water quality criteria. This will be related to the known water table and the nearest water consumption.

8.1 Tailings Pond Construction and Operation

The following is a brief description of the proposed method of depositing the tailings of the Mercur Gold Project into the tailings pond behind the Reservation Canyon Tailing Disposal Dam.

8.1.1 Dam Construction

The Reservation Canyon Tailing Disposal Dam will be continously constructed in three stages which have been nominally called the 2, 6, and 12 year stages scheduled for completion in 1983, 1985 and 1988. The dam is a zoned construction with an upstream and downstream shell, a sloping impervious core and an adjacent fine and coarse filter. See Figures No. 1.3, 1.4, 1.5, 1.6 and 1.7. This type of construction results in a dam which is

8.0 SEEPAGE (cont'd)

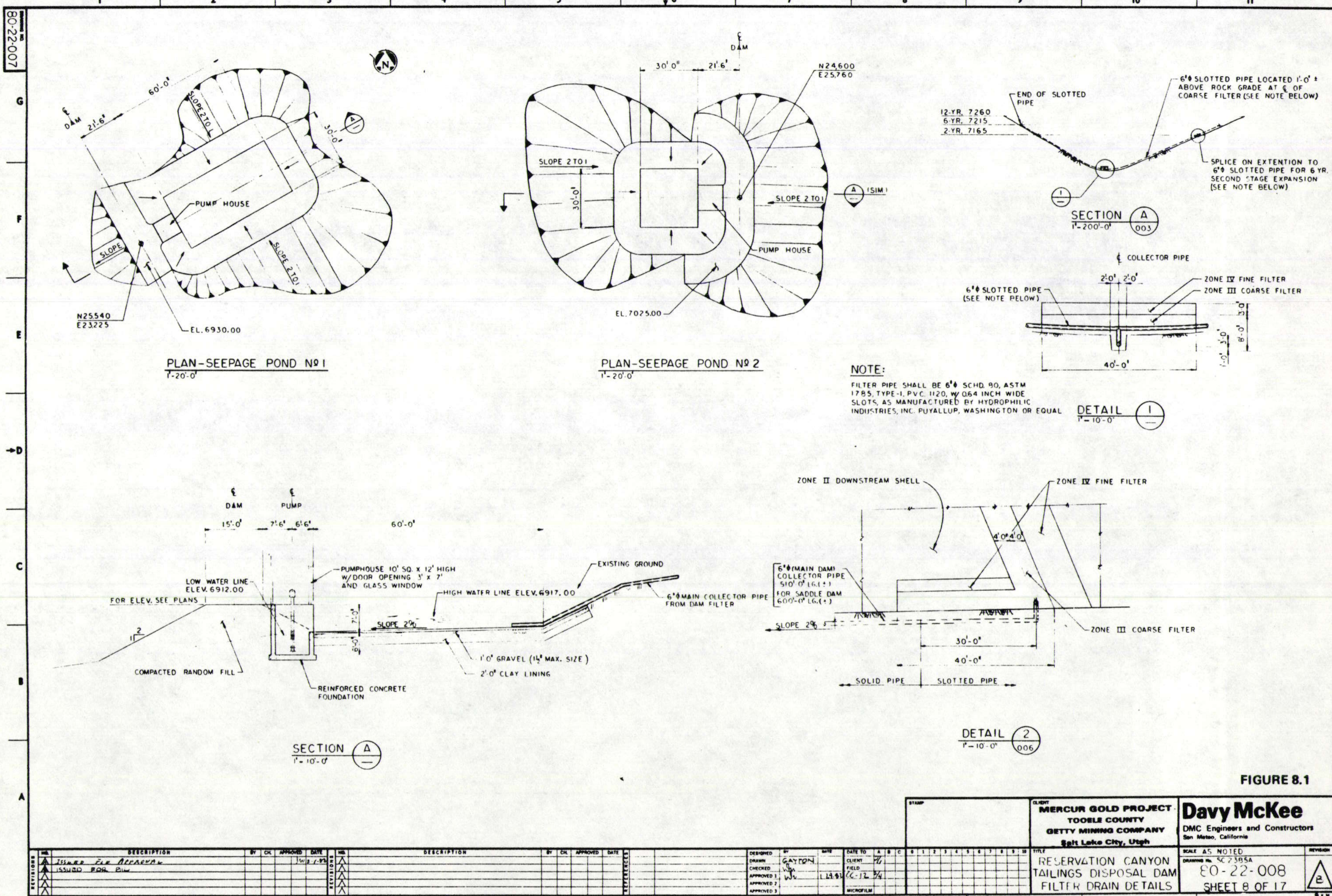
relatively impervious, moreover if some seepage does occur it is intercepted by the filters and collected in a downstream filter drain seepage pond. See Figure 8.1.

The dam is constructed largely from material taken from borrow pits which are located within the reservoir. See Figures 8.2, 8.3, and 8.4. The borrow pits are also planned in 2, 6 and 12 year stages. These pits have been shaped to facilitate the quick formation of a initial layer of solid tailings to seal the bottom and minimize seepage. In addition, the bottom of the 2 year borrow pit has been located within the Manning Canyon shale, an impervious material which will be used for the dam core.

This initial bottom pond is specificed to be leveled and recompacted which will result in an impervious basin in which a stable tailings dispoal mode can be established.

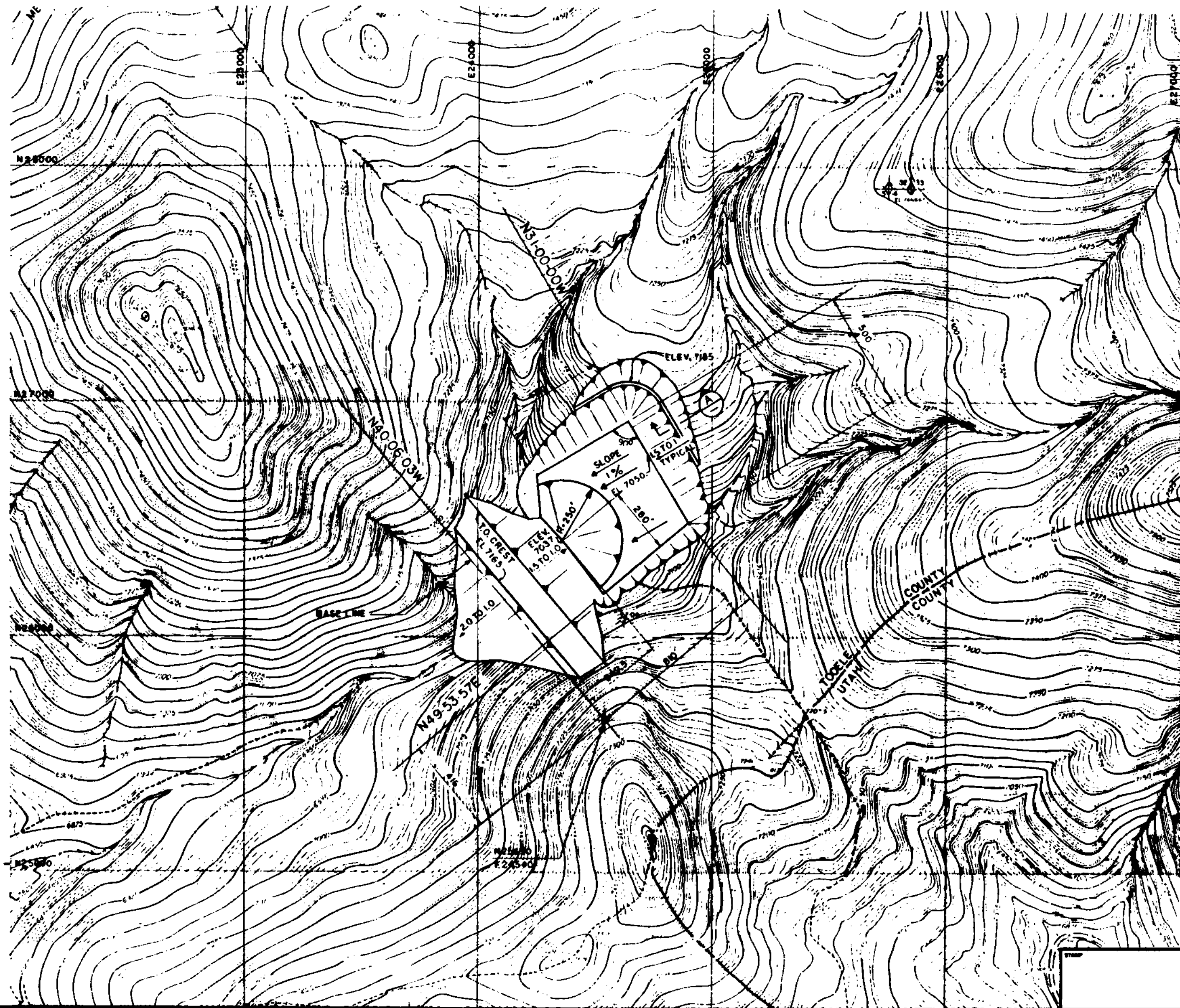
8.1.2 Tailings Disposal

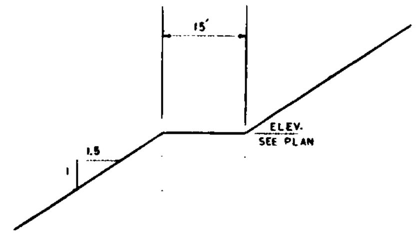
The tailings will be pumped as a slurry from the plant to the tailings pond via the saddle dam site. It will be distributed to the tailings pond from a upstream peripheral 8 inch distribution pipe which in turn will feed a number of flexible hose spigots. See Figures 8.5, 8.6 and 8.7. The disharge end of the hose will be adjusted to discharge horizontally and slightly above the top of solid



80-22-007
PLAN-SEEPAGE POND Nº1
1"-20'-0"
PUMP HOUSE
SLOPE 2 TO 1
SLOPE
60'-0"
21'-6"
30'-0"
N25540
E23225
EL. 6930.00
PLAN-SEEPAGE POND Nº2
1"-20'-0"
30'-0"
21'-6"
SLOPE 2 TO 1
PUMP HOUSE
N24,600
E25,760
EL. 7025.00
(SIM)
END OF SLOTTED PIPE
12-YR. 7260
6-YR. 7215
2-YR. 7165
6"Φ SLOTTED PIPE LOCATED 1'-0" ± ABOVE ROCK GRADE AT ℄ OF COARSE FILTER (SEE NOTE BELOW)
SPLICE ON EXTENTION TO 6"Φ SLOTTED PIPE FOR 6 YR. SECOND STAGE EXPANSION (SEE NOTE BELOW)
SECTION A 003
1"-200'-0"
℄ COLLECTOR PIPE
2'-0" 2'-0"
6"Φ SLOTTED PIPE (SEE NOTE BELOW)
ZONE IV FINE FILTER
ZONE III COARSE FILTER
40'-0"
8'-0"
NOTE:
FILTER PIPE SHALL BE 6"Φ SCHD. 80, ASTM 1785, TYPE-1, P.V.C. 1120, W/ 0.64 INCH WIDE SLOTS, AS MANUFACTURED BY HYDROPHILIC INDUSTRIES, INC. PUYALLUP, WASHINGTON OR EQUAL
DETAIL 1
1"-10'-0"
℄ DAM
℄ PUMP
15'-0"
7'-6"
6'-6"
60'-0"
LOW WATER LINE ELEV. 6912.00
FOR ELEV. SEE PLANS
PUMPHOUSE 10' SQ. X 12' HIGH W/DOOR OPENING 3' X 7' AND GLASS WINDOW
HIGH WATER LINE ELEV. 6917.00
EXISTING GROUND
6"Φ MAIN COLLECTOR PIPE FROM DAM FILTER
SLOPE 2%
1'-0" GRAVEL (1½" MAX. SIZE)
2'-0" CLAY LINING
COMPACTED RANDOM FILL
REINFORCED CONCRETE FOUNDATION
SECTION A
1"-10'-0"
ZONE II DOWNSTREAM SHELL
ZONE IV FINE FILTER
ZONE III COARSE FILTER
4'-0" 4'-0"
6"Φ (MAIN DAM) COLLECTOR PIPE 510'-0" LG. (±) FOR SADDLE DAM 600'-0" LG. (±)
SLOPE 2%
30'-0"
40'-0"
SOLID PIPE
SLOTTED PIPE
DETAIL 2 006
1"-10'-0"
MERCUR GOLD PROJECT
TOOELE COUNTY
GETTY MINING COMPANY
Salt Lake City, Utah
Davy McKee
DMC Engineers and Constructors
San Mateo, California
RESERVATION CANYON
TAILINGS DISPOSAL DAM
FILTER DRAIN DETAILS
SCALE AS NOTED
DRAWING No. SC 2385A
80-22-008
SHEET 8 OF 17
ISSUED FOR APPROVAL
ISSUED FOR BID
DRAWN GAYTON

FIGURE 8.1





SECTION A

NOTE:

1. CONFIGURATION OF BORROW PIT SHOWN ON DRAWING IS APPROXIMATE ONLY. ACTUAL CONFIGURATION SHALL BE MODIFIED AS REQUIRED TO PRODUCE ONLY SUFFICIENT QUANTITY AND QUALITY OF MATERIAL TO BUILD THE 2-YEAR DAM. ANY MODIFICATION TO BORROW PIT SHALL RETAIN THE GENERAL SHAPE AS SHOWN, WITH THE MAXIMUM SIZED FLAT BOTTOM PIT POSSIBLE AND BENCH AT ELEV 7155. QUALITY OF MATERIAL AND REQUIRED MODIFICATION OF BORROW PIT SHALL BE AS DIRECTED BY THE ENGINEER.

2. APPROXIMATE QUANTITIES OF MATERIAL FROM BORROW PIT:

MANNING CANYON SHALE	248,000 C.Y.
COLLUVIUM(OVERBURDEN)	820,000 C.Y.
TOTAL	1,068,000 C.Y.

3. AT THE COMPLETION OF BORROW, BOTTOM OF BORROW PIT SHALL BE SCARIFIED TO 12" DEPTH AND COMPACTED TO 95% DENSITY.

4. THE LOCATION OF BORROW PIT MAY BE MODIFIED AS REQUIRED BY THE ENGINEER TO ASSURE THAT ALL THE BOTTOM IS WITHIN THE MANNING CANYON SHALE.

FIGURE 8.2

MERCUR GOLD PROJECT
TOOELE COUNTY
GETTY MINING COMPANY
Salt Lake City, Utah

Davy McKee
DMC Engineers and Constructors
San Mateo, California

RESERVATION CANYON
TAILINGS DISPOSAL DAM
2-YEAR BORROW PIT

SCALE 1" = 200'
DRAWING No. SC 2365A
80-22-011
SHEET 11 OF 17

REV.	DESCRIPTION
A	Issued for Approval
B	Issued for Bid

DRAWING No. 80-22-011

NOTES

1. APPROXIMATE QUANTITIES OF MATERIAL FROM BORROW PIT:

MANNING CANYON SHALE	119,300 C.Y.
COLLUVIUM (OVERBURDEN)	614,400 C.Y.

2. SEE NOTE NO.1 DWG 8C-22-011

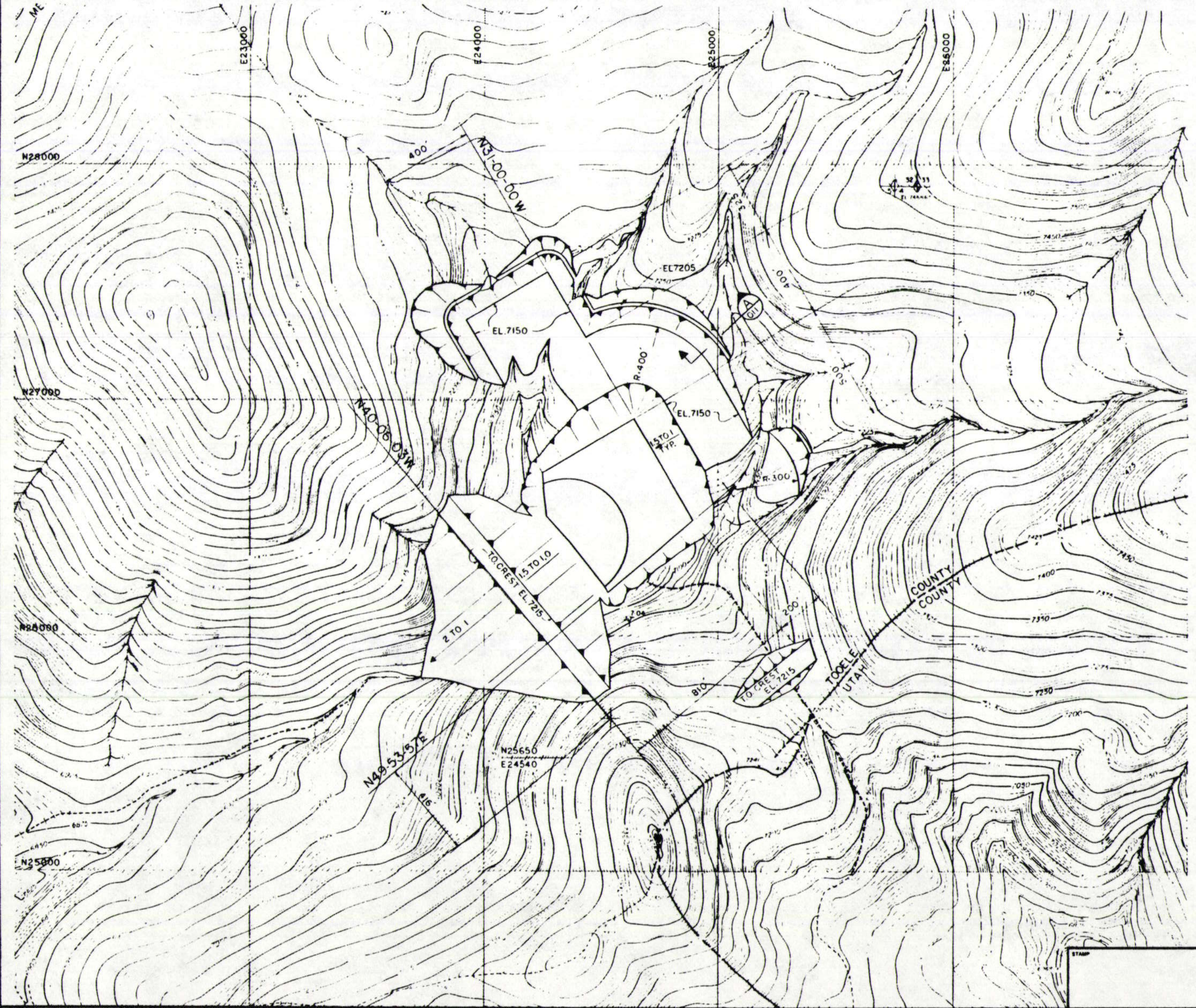


FIGURE 8.3

MERCUR GOLD PROJECT
TOOELE COUNTY
GETTY MINING COMPANY
Salt Lake City, Utah

Davy McKee
DMC Engineers and Constructors
San Mateo, California

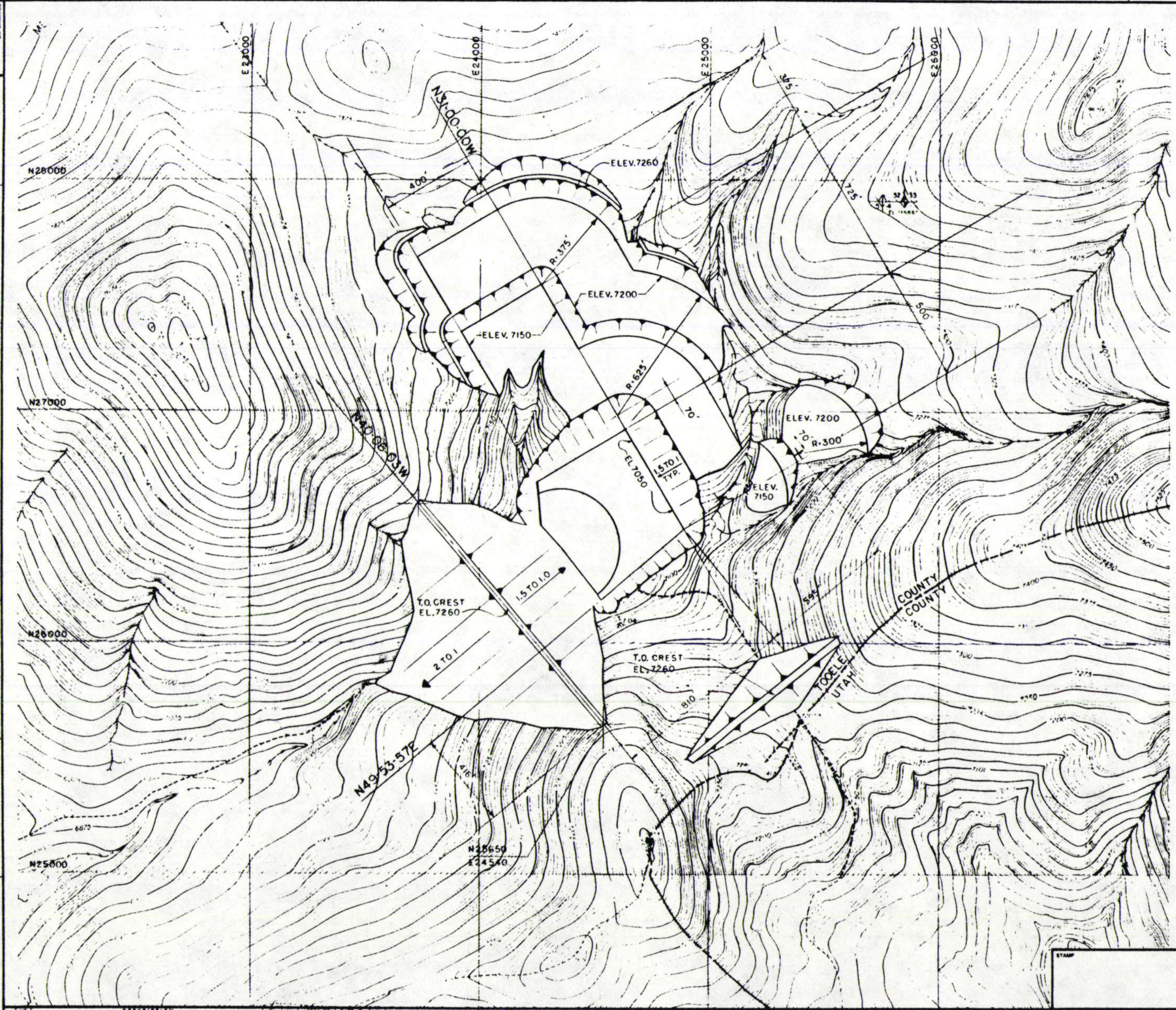
RESERVATION CANYON
TAILINGS DISPOSAL DAM
6-YEAR BORROW PIT

DRAWING No. 5C2385A
80-22-012
SHEET 12 OF 17

REVISION A

ISSUED FOR APPROVAL

DRAWING NO. 80-22-012



NOTES

1. APPROXIMATE QUANTITIES OF MATERIAL FROM BORROW PIT:

MANNING CANYON SHALE	104,000 C.Y.
COLLUVIUM (OVERHURDEN)	639,000 C.Y.
TOTAL	743,000 C.Y.

2. SEE NOTE NO. 1 DWG. 80-22-011

FIGURE 8.4

CLIENT: MERCUR GOLD PROJECT
TOOELE COUNTY
GETTY MINING COMPANY
Salt Lake City, Utah

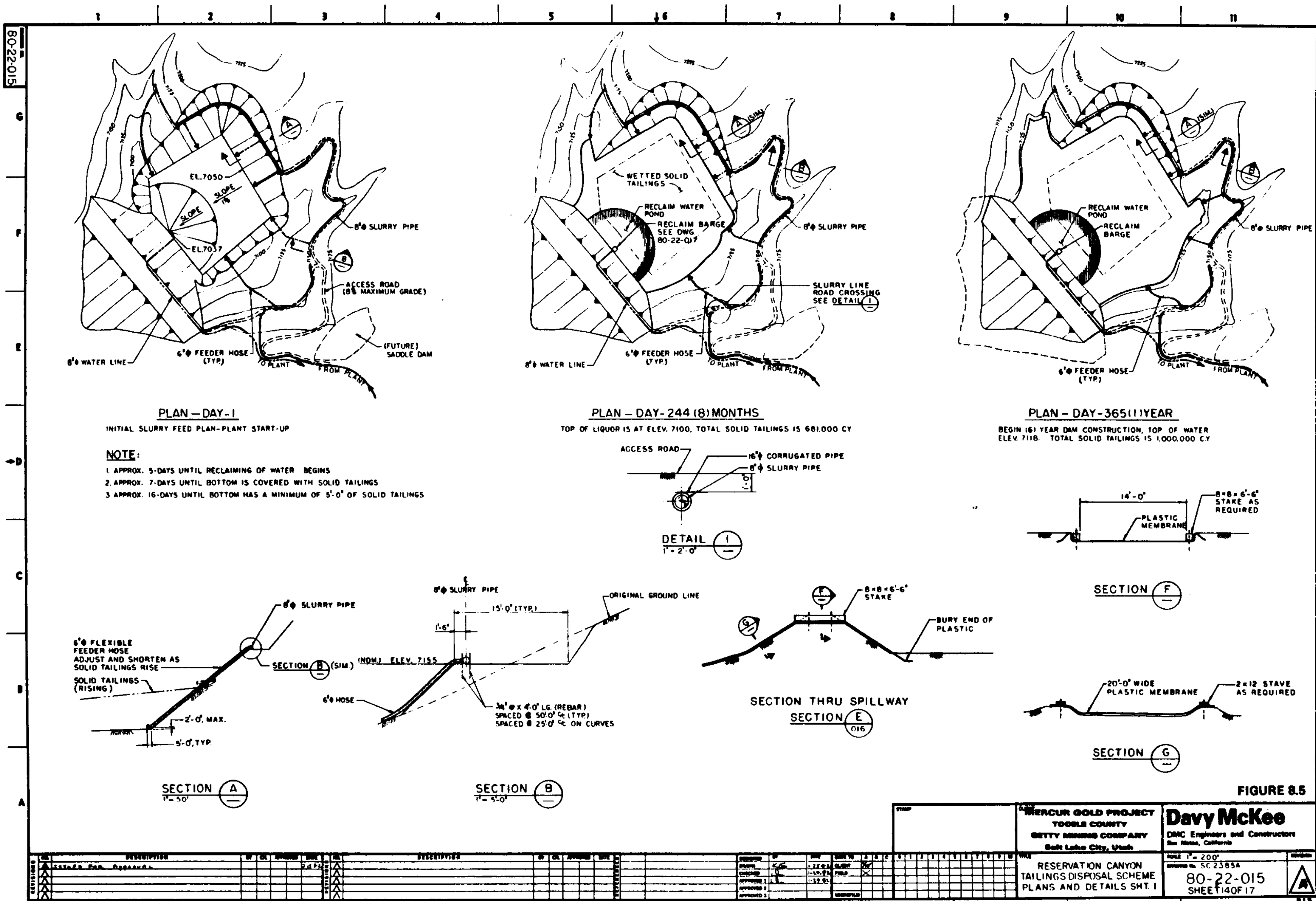
Davy McKee
DMC Engineers and Constructors
San Mateo, California

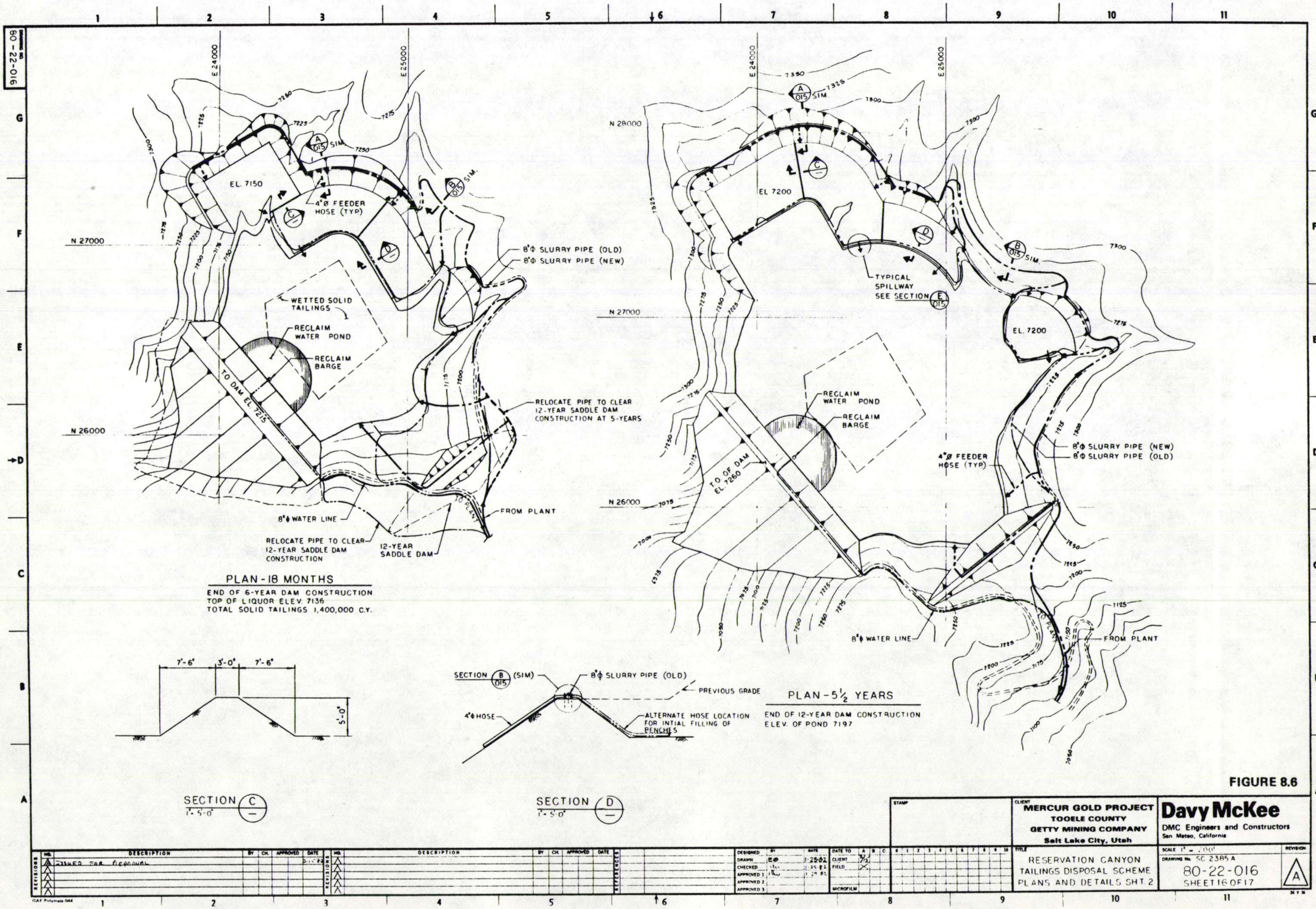
TITLE: RESERVATION CANYON
TAILINGS DISPOSAL DAMS
12 - YEAR BORROW PIT

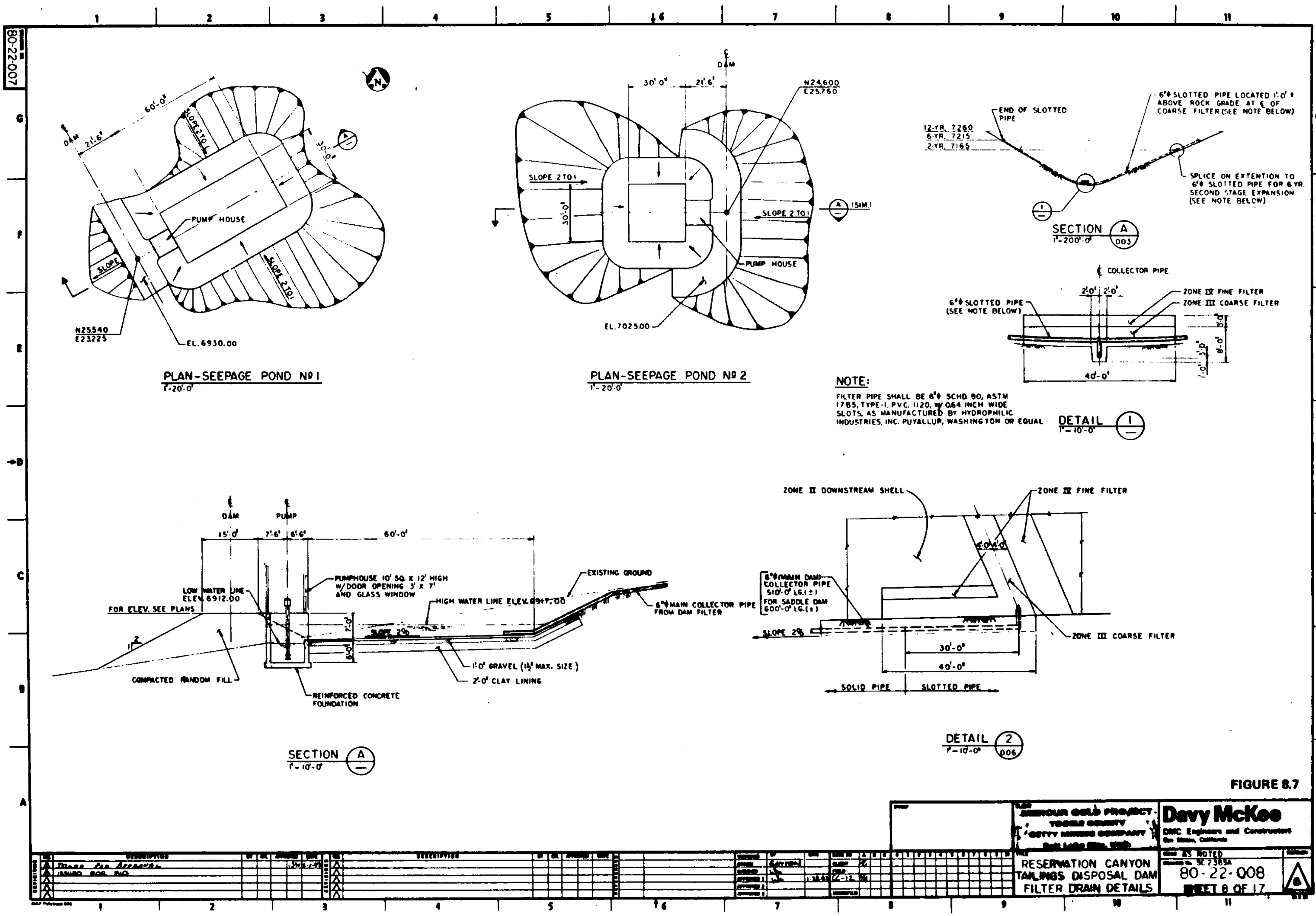
SCALE 1" = 200'
DRAWING No. 5C 23R5A
80-22-013
SHEET 13 OF 17
REVISION A

REVISIONS: A ISSUED FOR APPROVAL

DRAWING NO. 80-22-013


80-22-015
PLAN – DAY-1
INITIAL SLURRY FEED PLAN-PLANT START-UP
NOTE:
1. APPROX. 5-DAYS UNTIL RECLAIMING OF WATER BEGINS
2. APPROX. 7-DAYS UNTIL BOTTOM IS COVERED WITH SOLID TAILINGS
3. APPROX. 16-DAYS UNTIL BOTTOM HAS A MINIMUM OF 5'-0" OF SOLID TAILINGS
EL.7050
EL.7037
SLOPE
8"φ SLURRY PIPE
ACCESS ROAD (8% MAXIMUM GRADE)
(FUTURE) SADDLE DAM
8"φ WATER LINE
6"φ FEEDER HOSE (TYP.)
TO PLANT
FROM PLANT
PLAN – DAY-244 (8) MONTHS
TOP OF LIQUOR IS AT ELEV. 7100. TOTAL SOLID TAILINGS IS 681,000 CY
WETTED SOLID TAILINGS
RECLAIM WATER POND
RECLAIM BARGE SEE DWG 80-22-017
SLURRY LINE ROAD CROSSING SEE DETAIL 1
PLAN – DAY-365 (1) YEAR
BEGIN (6) YEAR DAM CONSTRUCTION. TOP OF WATER ELEV. 7118. TOTAL SOLID TAILINGS IS 1,000,000 CY
RECLAIM BARGE
ACCESS ROAD
16"φ CORRUGATED PIPE
8"φ SLURRY PIPE
DETAIL 1
1" = 2'-0"
14'-0"
PLASTIC MEMBRANE
8×8×6'-6" STAKE AS REQUIRED
SECTION F
6"φ FLEXIBLE FEEDER HOSE ADJUST AND SHORTEN AS SOLID TAILINGS RISE
SOLID TAILINGS (RISING)
SECTION B (SIM.)
2'-0" MAX.
5'-0" TYP.
SECTION A
1" = 50'
8"φ SLURRY PIPE
15'-0" (TYP.)
1'-6"
(NOM.) ELEV. 7155
ORIGINAL GROUND LINE
6"φ HOSE
3/4"φ × 4'-0" LG. (REBAR) SPACED @ 50'-0" C/C (TYP.) SPACED @ 25'-0" C/C ON CURVES
SECTION B
1" = 5'-0"
8×8×6'-6" STAKE
BURY END OF PLASTIC
SECTION THRU SPILLWAY
SECTION E 016
20'-0" WIDE PLASTIC MEMBRANE
2×12 STAVE AS REQUIRED
SECTION G
MERCUR GOLD PROJECT
TOOELE COUNTY
GETTY MINING COMPANY
Salt Lake City, Utah
Davy McKee
DMC Engineers and Constructors
San Mateo, California
RESERVATION CANYON TAILINGS DISPOSAL SCHEME PLANS AND DETAILS SHT. 1
1" = 200'
SC 2385A
80-22-015
SHEET 14 OF 17
FIGURE 8.5


PLAN-18 MONTHS
END OF 6-YEAR DAM CONSTRUCTION
TOP OF LIQUOR ELEV. 7136
TOTAL SOLID TAILINGS 1,400,000 C.Y.
EL. 7150
4"Ø FEEDER HOSE (TYP)
8"Ø SLURRY PIPE (OLD)
8"Ø SLURRY PIPE (NEW)
WETTED SOLID TAILINGS
RECLAIM WATER POND
RECLAIM BARGE
TO DAM EL. 7215
RELOCATE PIPE TO CLEAR 12-YEAR SADDLE DAM CONSTRUCTION AT 5-YEARS
8"Ø WATER LINE
FROM PLANT
TO PLANT
RELOCATE PIPE TO CLEAR 12-YEAR SADDLE DAM CONSTRUCTION
12-YEAR SADDLE DAM
PLAN-5½ YEARS
END OF 12-YEAR DAM CONSTRUCTION
ELEV. OF POND 7197
EL. 7200
TYPICAL SPILLWAY SEE SECTION E 015
TO OF DAM EL. 7260
SECTION C 1"-5'-0"
7'-6"
3'-0"
5'-0"
SECTION D 1"-5'-0"
SECTION B 015 (SIM)
4"Ø HOSE
PREVIOUS GRADE
ALTERNATE HOSE LOCATION FOR INTIAL FILLING OF BENCHES
FIGURE 8.6
MERCUR GOLD PROJECT
TOOELE COUNTY
GETTY MINING COMPANY
Salt Lake City, Utah
Davy McKee
DMC Engineers and Constructors
San Mateo, California
RESERVATION CANYON
TAILINGS DISPOSAL SCHEME
PLANS AND DETAILS SHT. 2
80-22-016
SHEET 16 OF 17



PLAN-SEEPAGE POND Nº 1
1" - 20'-0"
PUMP HOUSE
SLOPE 2 TO 1
SLOPE
60'-0"
21'-6"
30'-0"
DAM
N25540
E23225
EL. 6930.00
PLAN-SEEPAGE POND Nº 2
1" - 20'-0"
30'-0"
21'-6"
SLOPE 2 TO 1
PUMP HOUSE
N24600
E25760
EL. 7025.00
(SIM)
SECTION A 003
1" - 200'-0"
END OF SLOTTED PIPE
12-YR. 7260
6-YR. 7215
2-YR. 7165
6"Ø SLOTTED PIPE LOCATED 1'-0" ± ABOVE ROCK GRADE AT ℄ OF COARSE FILTER (SEE NOTE BELOW)
SPLICE ON EXTENTION TO 6"Ø SLOTTED PIPE FOR 6 YR. SECOND STAGE EXPANSION (SEE NOTE BELOW)
℄ COLLECTOR PIPE
6"Ø SLOTTED PIPE (SEE NOTE BELOW)
ZONE IV FINE FILTER
ZONE III COARSE FILTER
2'-0" 2'-0"
40'-0"
8'-0"
NOTE:
FILTER PIPE SHALL BE 6"Ø SCHD. 80, ASTM 1785, TYPE-I, PVC. 1120, W/ 0.64 INCH WIDE SLOTS, AS MANUFACTURED BY HYDROPHILIC INDUSTRIES, INC. PUYALLUP, WASHINGTON OR EQUAL
DETAIL 1
1" - 10'-0"
SECTION A
1" - 10'-0"
℄ DAM
℄ PUMP
15'-0"
7'-6"
6'-6"
60'-0"
LOW WATER LINE ELEV. 6912.00
FOR ELEV. SEE PLANS
PUMPHOUSE 10' SQ. X 12' HIGH W/DOOR OPENING 3' X 7' AND GLASS WINDOW
HIGH WATER LINE ELEV. 6917.00
EXISTING GROUND
6"Ø MAIN COLLECTOR PIPE FROM DAM FILTER
SLOPE 2%
7'-0"
6'-0"
1'-0" GRAVEL (1½" MAX. SIZE)
2'-0" CLAY LINING
COMPACTED RANDOM FILL
REINFORCED CONCRETE FOUNDATION
DETAIL 2 006
1" - 10'-0"
ZONE II DOWNSTREAM SHELL
ZONE IV FINE FILTER
ZONE III COARSE FILTER
6"Ø (MAIN DAM) COLLECTOR PIPE 510'-0" LG. (±)
FOR SADDLE DAM 600'-0" LG. (±)
SLOPE 2%
30'-0"
40'-0"
SOLID PIPE
SLOTTED PIPE
80-22-007
RESERVATION CANYON TAILINGS DISPOSAL DAM FILTER DRAIN DETAILS
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AS NOTED
80-22-008
SHEET 8 OF 17

FIGURE 8.7

8.0 SEEPAGE (cont'd)

tails. So as to minimize erosion and splashing. Discharge will be adjusted to form a beach of solid wetted tailings in the upstream reaches of the tailings pond with the reclaim pond against the upstream face of dam. It is planned to reclaim the maximum amount of clear liquor possible so as to minimize the reclaim pond size. Liquor will be reclaimed by a flotating barge which will skim the liquor from the top of the pond. The 8 inch diameter distribution pipe will be relocated for each dam construction phase and spigots hoses will be continuously adjusted to maintain the desired beach and pond configuration.

8.2 Tailings Distribution Model

8.2.1 Introduction

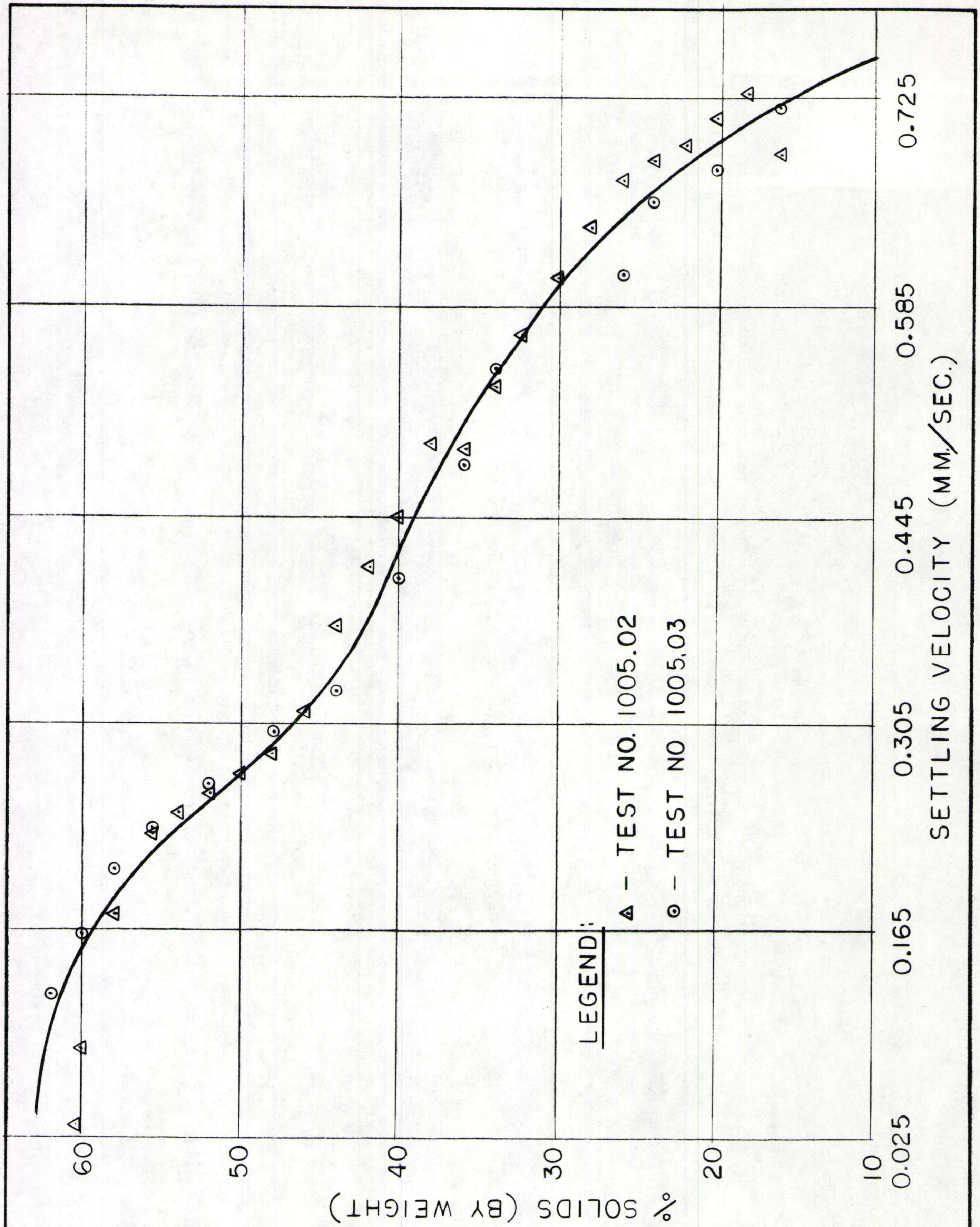
This section will describe the profiles of the tailings in both the underwater and wetted beach condition using a model.

The design and calculation of tailings density are based on the following data:

- The results of thickener settling tests (provided by Getty Mining Company) - Figure No. 8.8 (28).

- The results of screen analysis - Table No. 8.1.

- The data of pond capacity - Figures No. 1.4, 1.5, and 1.6.



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REVISION	DESCRIPTION	DRAWN	CK'D	DATE	DRWN		TITLE	SCALE	REV.
					CK'D		INTERFACE SETTLING VELOCITIES IN LAB TEST	DRAWING No. FIG. 8.8	△
					APP				
					APP				
					APP				

S ENG-8 8/79

Table 8.1

SCREEN ANALYSIS OF MERCUR TAILINGS

Particle Size (mm)	Passing by Percent Weight	Fraction by Weight
40 mesh	100	11.3
200 mesh	88.7	8.1
0.041	80.6	8.8
0.030	71.8	5.9
0.0217	65.9	6.5
0.0158	59.4	6.4
0.0117	53.8	6.5
0.0085	46.5	7.1
0.00611	39.4	7.0
0.00437	32.4	7.1
0.00314	25.3	4.7
0.00222	20.6	4.1
0.00135	16.5	16.5

- The data of seepage, evaporation and runoff.

- The theoretical references of disposal calculations (1, 19).

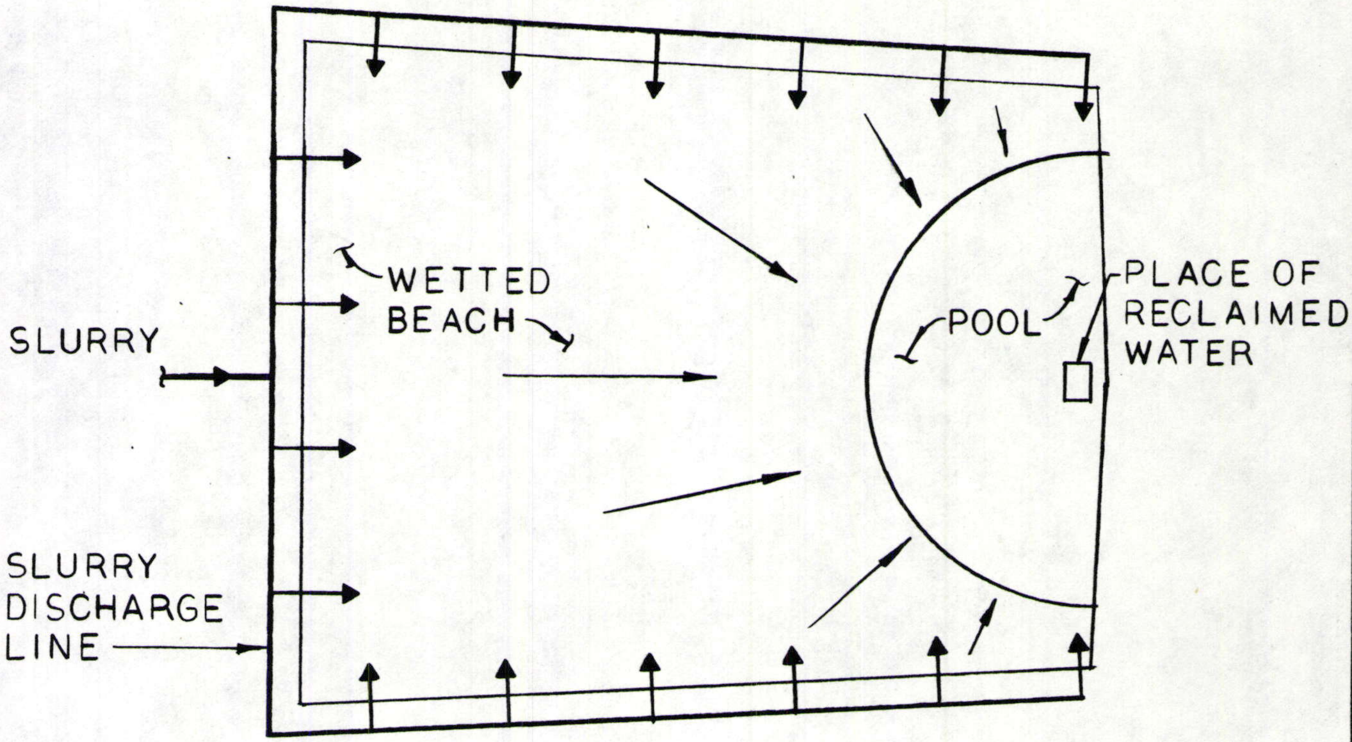
8.2.2 Tailings Disposal Model

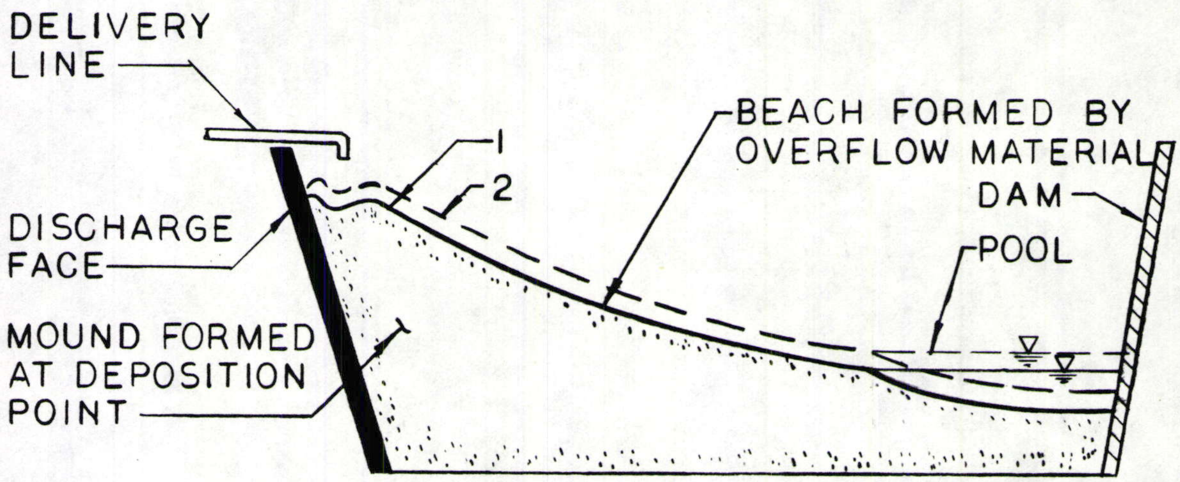
A tailings pond has a number of components, the discharge line and spigots, subarial wetted beach, subaqueous beach, reclaim water pool and reclaim point. See Figure 8.9.

The water pool limits the wetted beach length. Even though the top of the beach rises, the beach length will remain approximately constant if the water level of the pool is raised at the same rate as the discharge point rises. This model corresponds to the normal procedure of tailings disposal, when the beach profiles will be unchangeable but each point is rising at the same rate. Curve 1 (solid line) on Figure 8.9 shows the beach profiles at the given time and Curve 2 (broken line) corresponds to the next period of time.

In this case, the quantity of tailings which is deposited on unit surface of beach (wetted or underwater) will be constant for all points for certain periods of time. The solid quantities deposited on wetted and underwater beaches are proportional to their areas on the plane.

The area of the wetted beach will be changeable according to various elevations (see Figure 8.9) and will be equal to the total area minus the pool area.





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REVISION	DESCRIPTION	DRAWN	CK'D	DATE		TITLE	SCALE	REV.
					DRWN	DEVELOPMENT OF BEACH ON TAILINGS POND		
					CK'D		DRAWING No.	
					APP		FIG. 8.9	△
					APP			
					APP			

S ENG-8 8/79

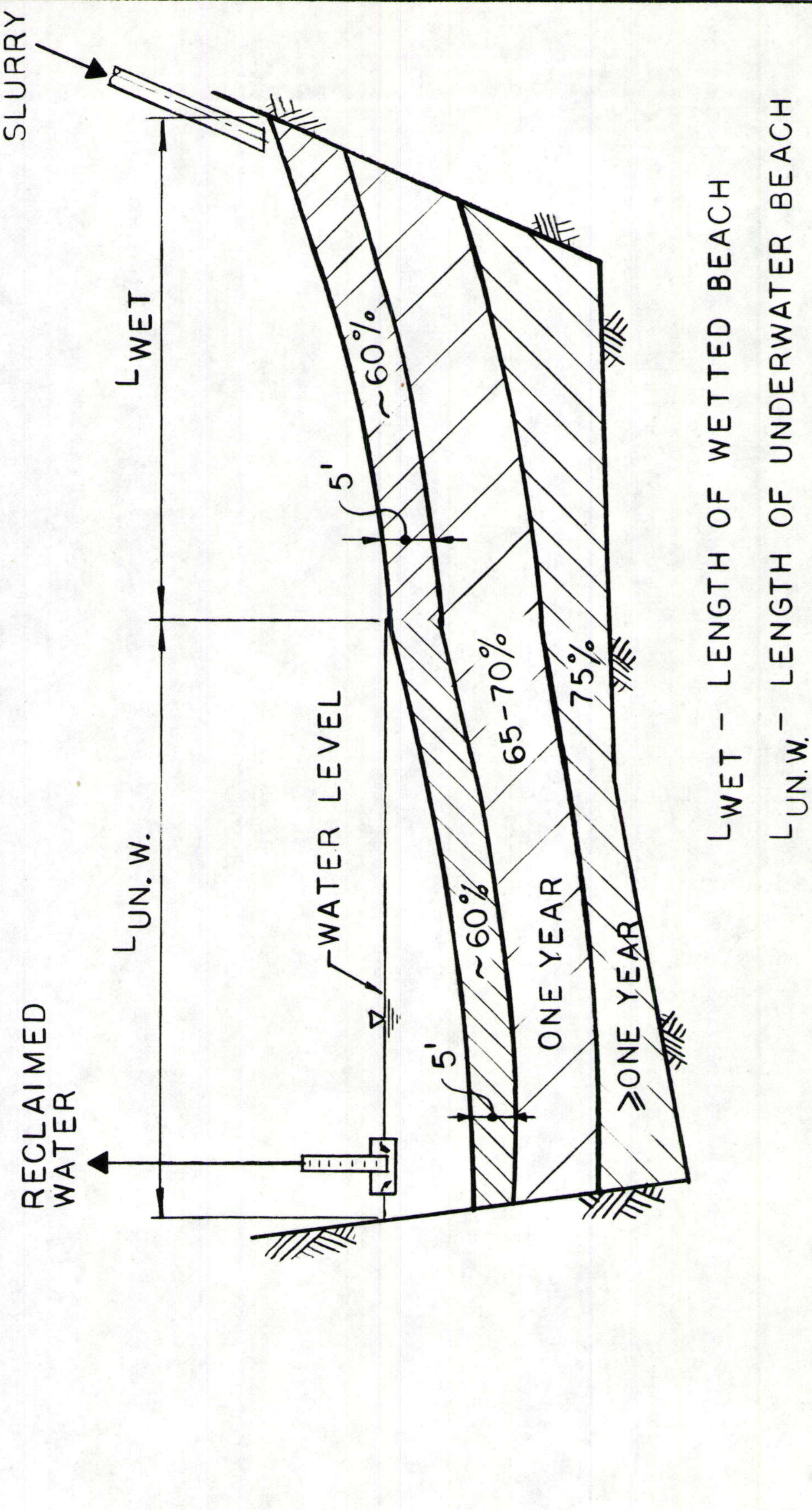
8.0 SEEPAGE (cont'd)

To manage the form and the size of pool and to maintain it within the given ranges, the discharge points must be changeable and movable along the discharge line.

The disposal area is planned to be in service for 12 years. In this case, it is very important to calculate or to assume the properties of tailings density and their change in time. See Figure No. 8.10. The percent of solids of slurry in laboratory settling tests was in the range of 60-62% by weight or 36.6-38.6% by volume after 28 hours of settling. Based on this data, it can be assumed that the tailings will consolidate to about 60% solids by weight within a short period fo time. This is compared to the mill discharge slurry which is about 45% solids by weight.

The further filling up of the tailing impoundment creates layers of solids which press the lower layers and make them more consolidated. It can be assumed that the tailings density in the impoundment will be increased up to about 65-70% by weight or 42-48% by volume after the first year of residence in the pond.

After one year, the tailings density will be increased up to 75% by weight or 53.6% by volume. Further consolidation of tailings near the bottom of the pond can be



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REVISION	DESCRIPTION	DRAWN	CK'D	DATE				TITLE	SCALE	REV.
					DRWN			DISTRIBUTION OF SOLID CONCENTRATIONS IN TAILINGS DISPOSAL	DRAWING No. FIG. 8.10	△
					CK'D					
					APP					
					APP					
					APP					

S ENG-8 8/79

expected up to densities of 83% solids and more at which point their permeabilities will decrease to very low values. When this highly consolidated liner of tailings is formed, it's impermeability will retard consolidation of the rest of the tailings.

8.2.3 Wetted and Underwater Beach Profiles

The pond area receives tailings from the perimeter discharges to form a wetted beach. This type of slurry discharge makes it possible to manage the form of pool. The best pool form is a semicircle because the conditions of settling will be the same independent of the slurry discharging points. The place of reclamation of clear water is the center of this semicircle.

8.2.3.1 Wetted Beach

The profile of the wetted beach has a parabolic shape and could be described by the following equation:.

$$y = i_{av}L(1- \frac{x}{L})^n$$

where (see Figure No. 8):

y and x - coordinates

L - the total length of a wetted beach

$i_{av} = \frac{H'}{L}$ - the average slope of the beach

H^1 = y @ x = 0

H^1 - total drop elevation

n - parameter depend on the particle size distribution of the deposited material.

n = 4.0 - for gold tailings (1)

8.2.3.2 Underwater Beach

There is a little information about the profile of the tailings deposited underwater in the pool. The equation suggested by Melentev (19) in an exponential form of the profile can be applied for the general calculations See Figure No. 8.11.

$$y' = H \left[1 - e^{-2} \left(\frac{W\ Set}{W\ Water} \right)^{1/2} \frac{X}{H} \right]$$

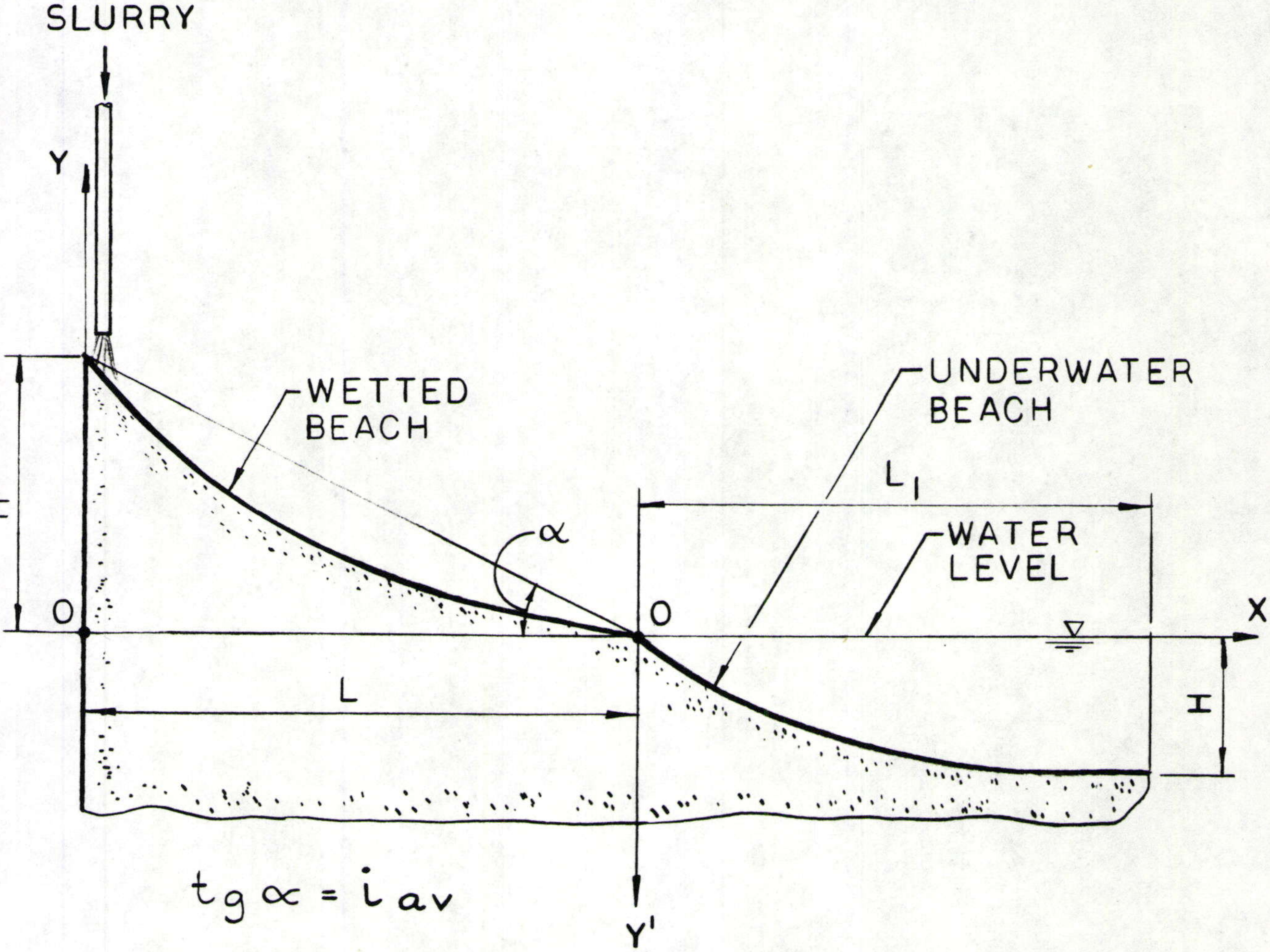
where

y', x - coordinates

H - the water depth of pool

W_{water} - the clear water velocity discharged in pool.

W set - the settling velocity found from the thickener settling test (See Figure No. 8.8).



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REVISION					DRWN		
					CK'D		
					APP		
					APP		
					APP		

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TITLE: BEACH PROFILES

SCALE:

DRAWING No.: FIG. 8.11

REV.: △

S ENG-8 8/79

8.0 SEEPAGE (cont'd)

8.2.4 Results of Calculations

All calculations concerned with tailings disposal were made in a conservative manner as follows:

The solid size distribution used in calculations was the smallest from the tests. In the actual case, the solid sizes will probably be larger and thus the reclaimed water will be cleaner.

The average retention time of water in the pool is about 65 hours. This is about 10 times more than the time provided for the laboratory settling tests.

It is assumed that all discharged slurry and runoff water come into the pool along the wetted beach but in reality a part of the water will be percolated through tailings decreasing the water solid mixing in the pool.

In order to increase the efficiency of tailings volume and to reclaim water with a high degree of clarity, the slurry discharging points and the quantities of reclaimed water have to be regulated to maintain the semicircular form of pool.

The solid concentration of tailings in the first year will be in the range of 65-70% by weight and after one year, 75% by weight.

8.0 SEEPAGE (cont'd)

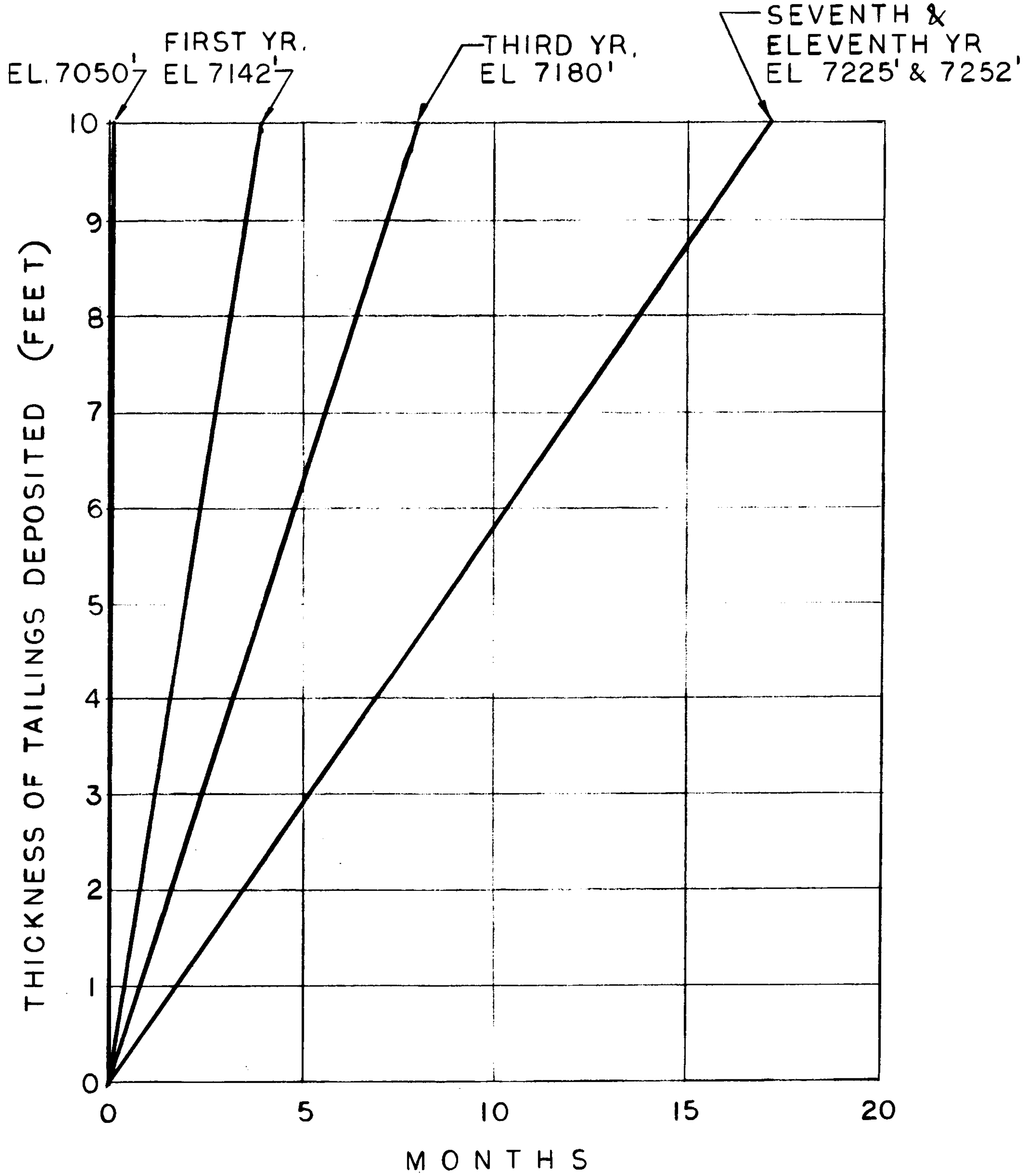
The initial slope of the wetted beach at the discharge point is about 17% and the average slope for 75% of the wetted beach length above the water pool is less than 1.8%.

The average slope of underwater beach is not less than 3% and the local slope near the pool edge will be about 11%.

8.3 Seepage Model

Recently developed seepage techniques describing the flow beneath tailings impoundment (18) were used to evaluate the seepage rate and the potential migration of wetting fronts away from the tailings impoundment. The impoundment will be filled with tailings at a constant rate. The seepage rate into the pervious foundation material at any time and elevation is controlled by the thickness of the less pervious tailings at the particular point of interest. The deposited tailings has an initial permeability of 2×10^{-6} cm/sec which changes to 2×10^{-7} cm/sec when its thickness reaches 10 ft or more. To preserve conservatism of the seepage analysis, it was assumed the tailings solids were laid horizontally and always covered uniformly by a thickness of 6 inches of liquor. Note that the actual operation of the pond will develop a small, pool instead of a shallow, large pool. Because the seepage is more sensitive to pool area than depth, the model criteria provide for a higher calculated seepage rate than should actually occur. The rate of filling is a function of tailings discharge rate and the area-capacity relationship of the impoundment. The tailings deposition rates at different elevations are shown in Figure 8.12. As the tailings level moves up during the 12 year operation, the model seepage rate tends to increase because the contact time between the tailings liquor and the subsurface material increases and build-up rate of tailings thickness decreases.

A one-dimensional seepage model was used to simulate seepage from the liquor pool through the deposited tailings into the foundation material. The analysis was performed in two cases: one through the continuously deposited tailings and the other through limited thickness of tailings. The latter case applies to the seepage of liquor into the subsurface along a sloping face. Since the tailings solids are of fine texture (89% minus 200 mesh), it is expected that the fine particles will be suspended uniformly in the bottom 6 inches of pool liquor and those particles in contact with the sloping bed will be trapped. (Settling rate of the finest portion of particles is estimated to be 1 ft/hr). Thus, a layer of one-inch constant thickness of tailings was assumed along the sloping face. A schematic



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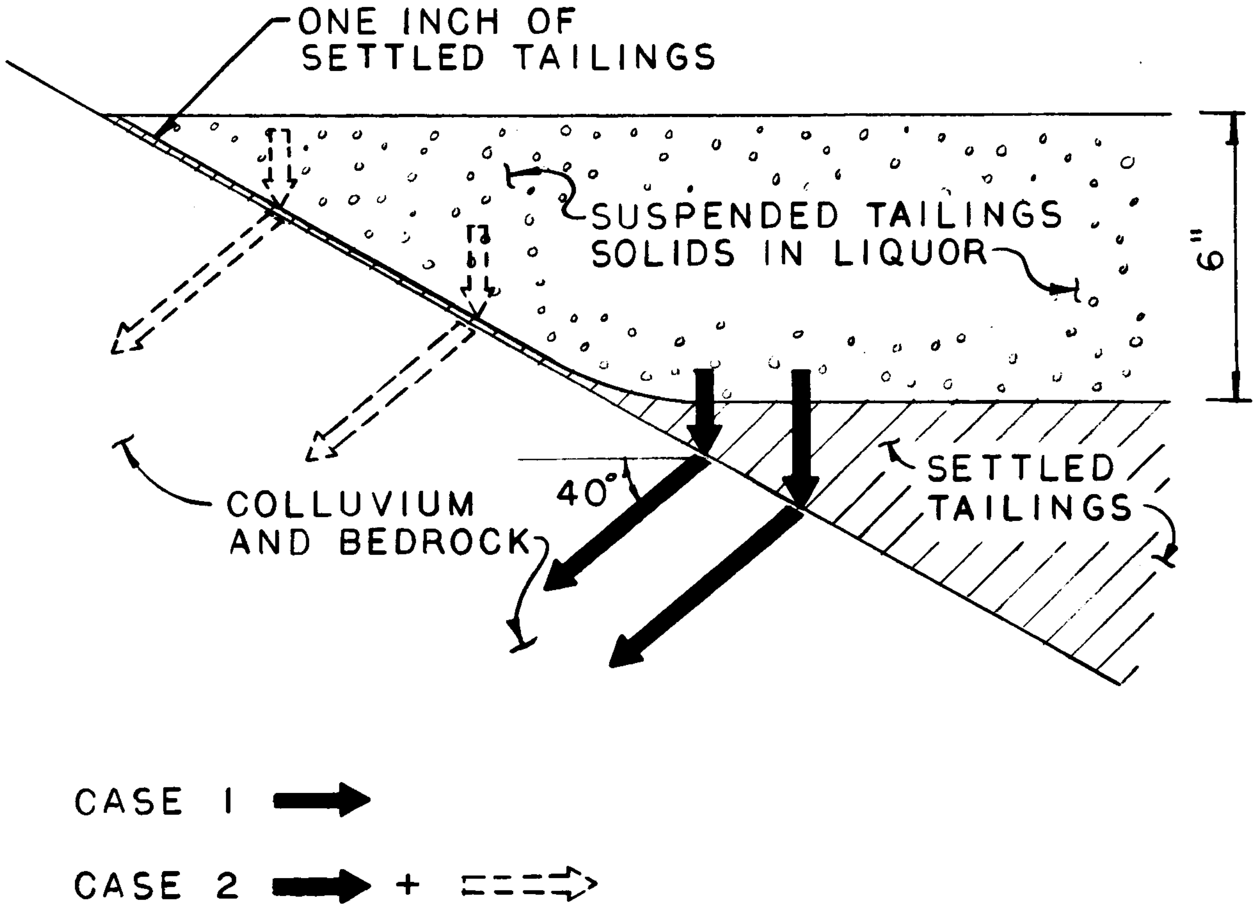
REVISION	DESCRIPTION	DRAWN	CK'D	DATE				TITLE	SCALE	REV.
					DRWN			TAILINGS DEPOSITION RATE AT DIFFERENT ELEVATIONS	DRAWING No. FIG. 8.12	
					CK'D					
					APP					
					APP					
					APP					

S ENG-8 8/79

diagram showing the seepage pattern at the bottom of the impoundment is presented in Figure 8.13. Reiterating two case studies were performed. Case 1 includes the seepage through the continuously deposited tailings and Case 2 includes Case 1 and the seepage through the one-inch constant thickness of tailings along the sloping face. Case 1 thus models the pool never contacting the foundation soils and Case 2 models the occurrance of the flooding of the beach with 6 inch of pool against the soil.

8.3.1 Subsurface Material

The thickness of the overburden soil was found in field exploration to be variable and generally increased from zero at the crest elevation of the dam (12-year stage) to about 30 feet at the bottom of the canyon. The overburden encountered on the hillsides was mostly colluvial soil, generally brown colored, consisting predominantly of gravel and cobbles derived from limestone bedrock and found in a matrix of silty sand with a slight clay content. Bedrocks encountered were gray to dark gray limestone and dark gray to black shale below the overburden soils. The limestone was relatively low to moderately permeability (less than 100 to 5000 ft/yr). Bedrock of the Upper Great Blue limestone is moderately permeable (1000 to 3000 ft/yr) due to fracturing while the Manning



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REVISION	DESCRIPTION	DRAWN	CK'D	DATE

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TITLE: FLOW PATTERN IN SEEPAGE MODEL

SCALE

DRAWING No. FIG.8.13

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S ENG-8 8/79

8.0 SEEPAGE (cont'd)

Canyon shale is low in permeability except in its upper weathered surface (7). This upper layer of shale will be excavated for core construction.

These permeability values represent either the porous medium permeability or the equivalent fracture permeability of the bedrock. In the seepage analysis, the colluvium, shale, and limestone were treated as one layer with a conservative permeability of 2.8×10^{-3} cm/sec (3000 ft/yr).

8.3.2 Modeling Approach

The seepage was modelled to follow the general direction of the bedding which dips in an average of 40° to the northeast. A partially-saturated regime above the wetting front was found to dominate throughout the seepage process due to the low permeability of the tailings.

The hydraulic properties of the tailings and the subsurface material used in the analysis are listed in Table 8.2. The seepage was simulated through successive time steps with varying tailings thicknesses as shown in Table 8.3.

8.3.3 Results of Analysis

The results of the analysis of Case 2 show that the distance of percolation of the liquor into the alluvium

TABLE 8.2

MODEL INPUT PARAMETERS

Alluvium and Bedrock:		
Saturated permeability	=	2.85×10^{-3} cm/sec
Initial volumetric water content	=	0.02
Residual volumetric water content	=	0.02
Pore size distribution index	=	4
Porosity	=	0.32
Displacement head	=	-15 cm
Constant head above tailings	=	15 cm

Tailings Permeability (cm/sec):

2.0×10^{-6} when thickness $<10'$

2.0×10^{-7} when thickness $\geqslant 10'$

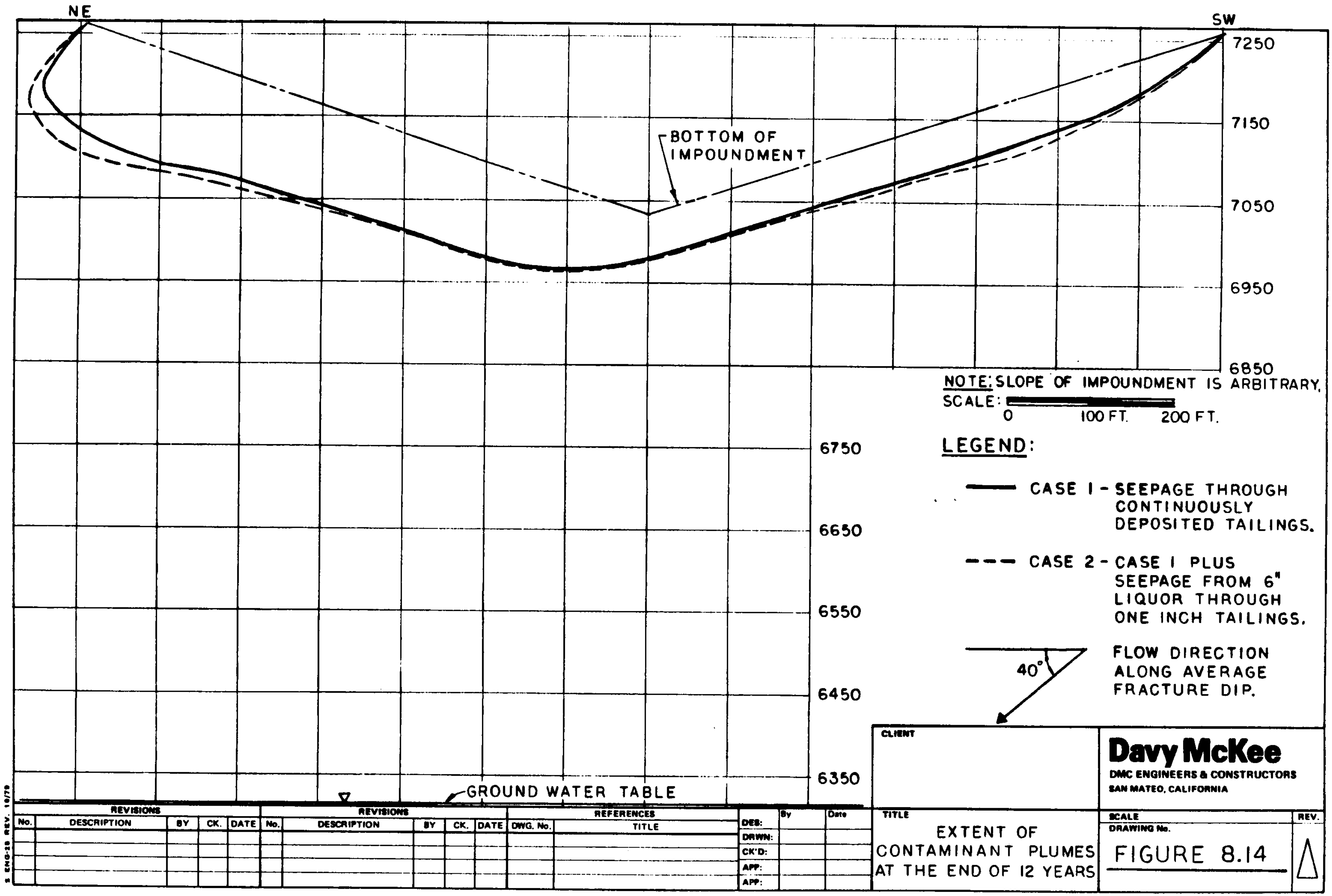
TABLE 8.3

THICKNESS OF TAILINGS VS. TIME STEP

Time step	Tailings thickness (ft)		
	From	To	Average
1	0	0.17	0.083
2	0.17	0.50	0.33
3	0.50	5.0	2.75
4	5.0	10.0	7.50
5	10.0	Variable > 10	Variable

and bedrock varies from 128 ft and 129 ft at elevation 7050 ft (close to the bottom of the impoundment) to 148 ft and 172 ft at elevation 7225 ft during the 12-year operation for Cases 1 and 2 respectively (Figure 8.14). The seepage rates during this period are presented in Figures 8.1.5 and 8.1.6. The above distances were calculated along a 40° dip direction in the subsurface material. The seepage characteristics at the end of 12 year for both cases are shown in Table 8.4.

It was estimated that the unsaturated seepage front would require up to 88 years to migrate down-dip to reach the closest aquifer which is approximately 700 ft vertically the bottom of the impoundment. The significant depth to the aquifer and the relatively short duration of the anticipated waste disposal operation (12 years) preclude the possibility of occurrence of subsequent phases of seepage; namely, the development of a major ground water mound and the establishment of steady seepage conditions between the disposal areas and the underlying aquifer. Minor build-ups of perched seepage water could occur locally in areas where soil and rock layers of varying permeabilities are encountered. The simulation of this phenomenon, however, falls beyond the scope of the present study and, in any case, carries little significance for the present evaluation.


NE
SW
7250
7150
7050
6950
6850
6750
6650
6550
6450
6350
BOTTOM OF IMPOUNDMENT
GROUND WATER TABLE
NOTE: SLOPE OF IMPOUNDMENT IS ARBITRARY.
SCALE: 0 100 FT. 200 FT.
LEGEND:
CASE 1 - SEEPAGE THROUGH CONTINUOUSLY DEPOSITED TAILINGS.
CASE 2 - CASE 1 PLUS SEEPAGE FROM 6" LIQUOR THROUGH ONE INCH TAILINGS.
40°
FLOW DIRECTION ALONG AVERAGE FRACTURE DIP.
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TITLE
EXTENT OF CONTAMINANT PLUMES AT THE END OF 12 YEARS
SCALE
DRAWING No.
FIGURE 8.14
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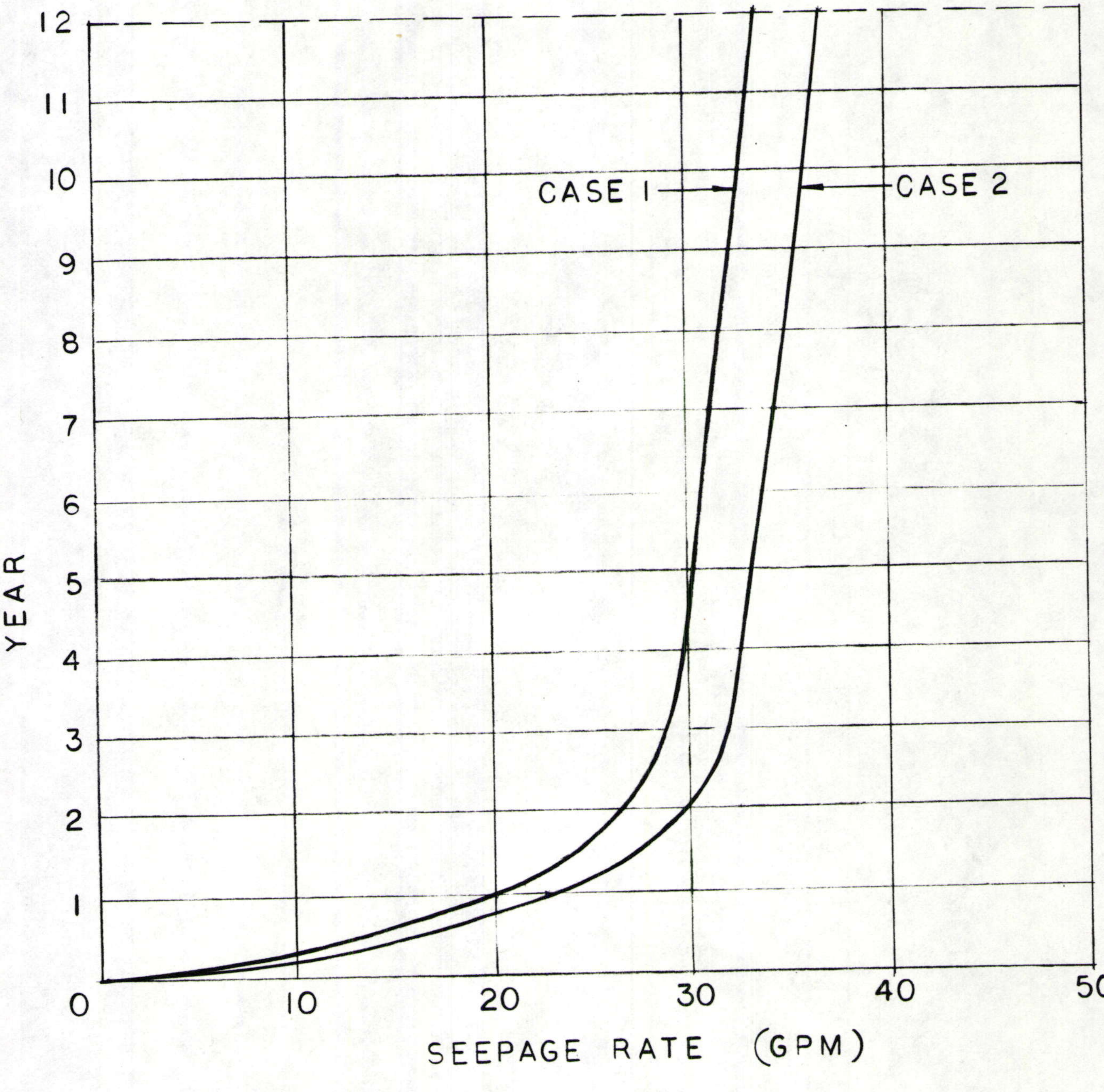

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REVISION	DESCRIPTION	DRAWN	CK'D	DATE		TITLE	SCALE	REV.
					DRWN	SEEPAGE RATE VS. TIME	DRAWING No. FIG. 8.15	
					CK'D			
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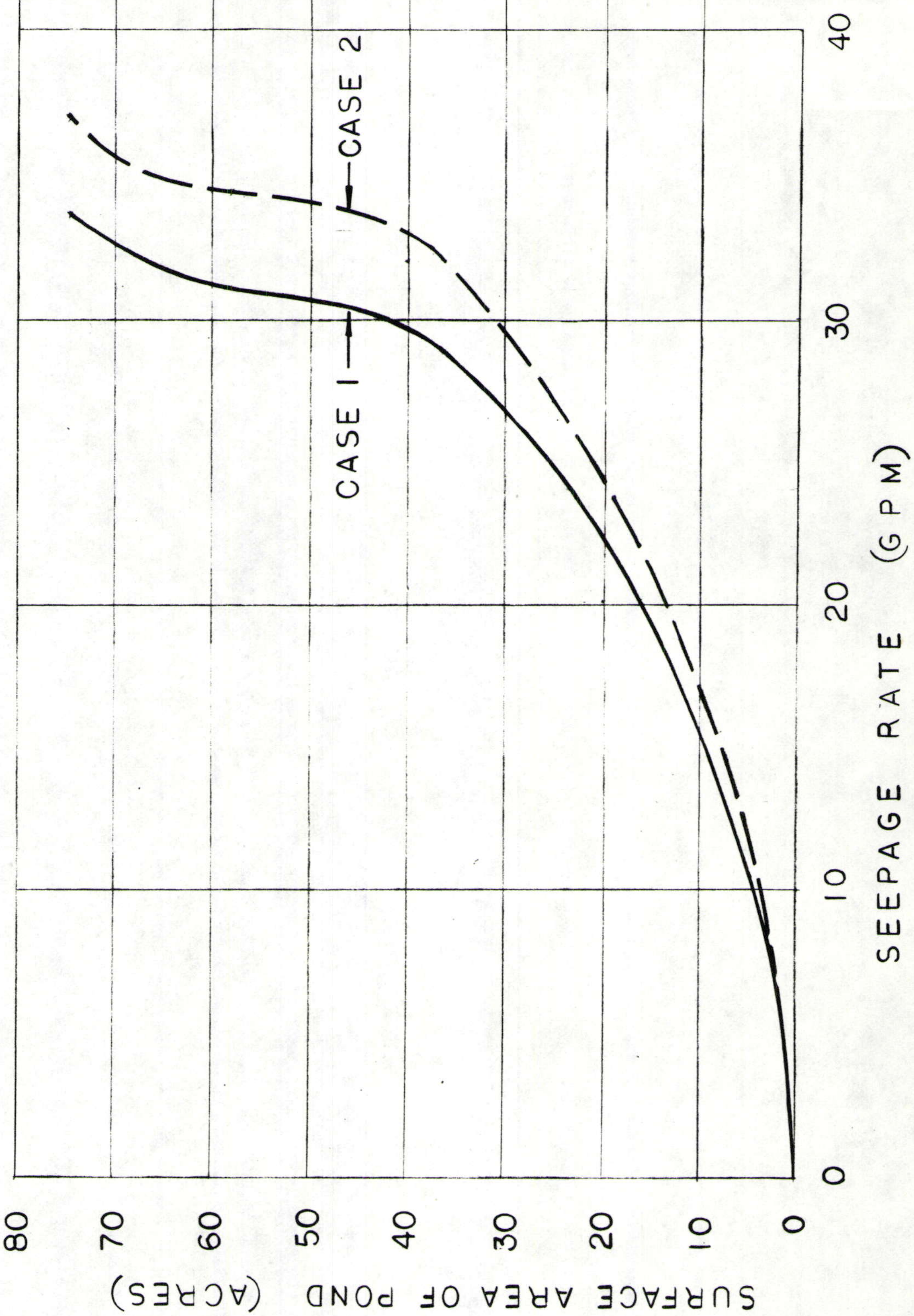
S ENG-8 8/79



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REVISION DESCRIPTION	DRAWN	CK'D	DATE	DRWN / CK'D / APP / APP / APP	TITLE	SCALE / DRAWING No.	REV.
					SEEPAGE RATE VS. SURFACE AREA OF POND	FIG. 8.16	△

S ENG-8 8/79

TABLE 8.4

SEEPAGE CHARACTERISTICS AT THE END OF 12 YEARS

Case	Average total seepage rate (gpm) for 12 years	Total quantity of seepage (Ac/ft)	Maximum seepage depth (ft) 40° dip	Estimated time for liquor to reach ground - water table (yr)
1	29	561	148	88
2	32	620	172	88

8.0 SEEPAGE (cont'd)

The Case 2 seepage analysis assumes all tailings particles will be carried to the pond during discharge and no beach will be developed. The actual condition would be the formation of a wet beach above the pond and only the finest particles will end up in the pond water.

The bottom of the impoundment is underlain by shale bedrock the top portion of which will be compacted during the preparation of the foundation for the initial stage of the impoundment. The compacted shale will have a permeability less than that used in the seepage analysis. Seepage will be minimized as tailings accumulate underwater and along the slope as wet beaches.

In conclusion, the seepage estimated by the model will be conservative and the actual condition will probably be between Cases 1 and 2.

Because the pool will always be maintained above a beach of impermeable tailings the seepage will be reduced to low values. This tailings beach will provide effective seepage control. The Case 1 model predicts an average total seepage rate of 29 gpm. Further reductions of seepage by the use of liners is technically difficult due to the steep topography of the site.

8.0 SEEPAGE (cont'd)

8.3.4 Limitations

The McWhorter-Nelson model provides reasonably simple and reliable engineering procedures for the estimation of seepage rates below the tailings impoundment (18). It provides relatively accurate estimates of seepage losses necessary for the assessment of environmental impacts and for water balance computations, the model implies the following assumptions:

The model is one-dimensional.

The degree of saturation or desaturation is uniformly distributed on either side of a wetting front.

The rate of flow at a given time is the same at all points along the seepage path.

The model computes the migration of water from the impoundment.

Material properties are isotropic.

The following modifications are made to the McWhorter-Nelson seepage model in the present study to simulate as closely as possible the real condition:

Model flow path along 40° dip in the subsurface material.

Thickness of tailings varies with time so that flow rate varies with time. In this way, the degree of saturation changes with time above the wetting front.

The McWhorter-Nelson approach represents an efficient tool in evaluating seepage for engineering purposes and the use of this method for waste disposal has been favorably considered by the Nuclear Regulatory Commission (NRC) and State Regulatory Agencies (25).

8.4 Water Balance

At the current time, we expect a negative water balance in the tailings pond (Table No. 8.5) (Figure 8.17). There are several factors controlling this negative water balance. We expect average evaporation of 42 in/yr to exceed average precipitation of 17.4 in/yr (45% snow). We will have water lost to seepage from the tailings pond of 20-34 gpm as well as water entrained within the tailings in the pond (228-245 gpm). The resulting balance indicates 333-411 gpm of decant water being returned from the pond to the mill.

The above values are dynamic and will seek an equilibrium as parameters change. For example, as seepage control measures are made, seepage rate would decrease, producing a pond of larger size which would increase evaporation. This would increase the area available over which seepage can take

TABLE NO. 8.5

WATER BALANCE

RESERVATION CANYON TAILING POND (GPM)

INPUT

Years	Pond Area	Mill Discharge	Precip- itation	Run Off	Pond Inflow
1	16.0	615	15	81	711
3	35.8	615	32	78	725
7	58.1	615	52	76	743
12	74.5	615	67	74	756

OUTPUT

Years	Evap- oration	H_2O in Tails	Seepage	Pond Outflow	Avail Decant	Decant	Deficiency
1	35	245	20	300	411	440	29
3	78	228	29	335	390	440	50
7	126	228	31	385	358	440	82
12	161	228	34	423	333	440	107

Table NO. 8.5 (cont'd)

ASSUMPTIONS: Reservation Canyon

42.0 in/yr evaporation

17.4 in/yr precipitation (30)

13% runoff (14)

12% recharge to ground water (14)

75% evapotranspiration

440 gpm - decant to mill

615 gpm - tails slurry to pond

228-245 gpm - returned in tailing

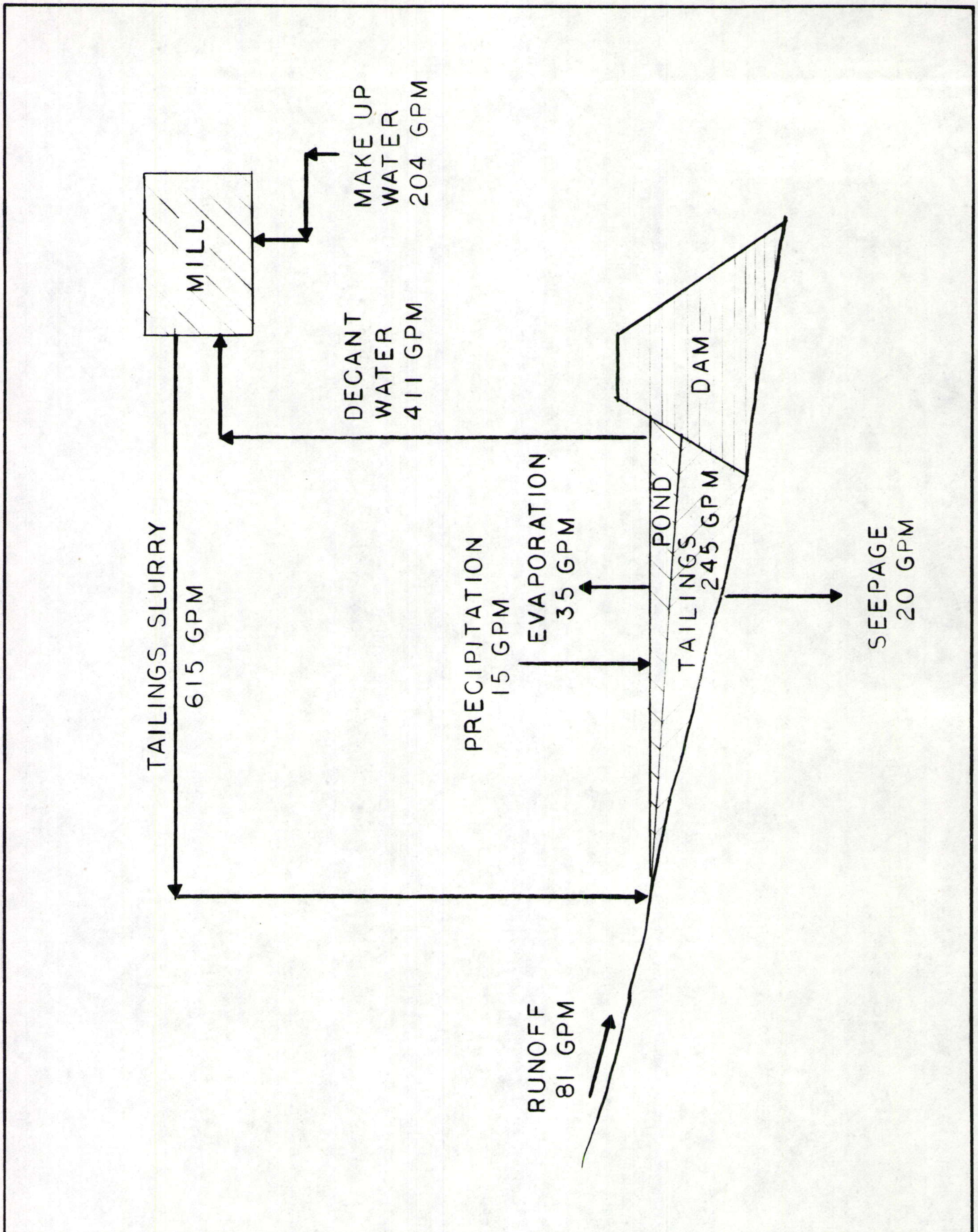
788 acres drainage basin

Inflow to Pond = Discharge from Mill + Precipitation + Runoff = A

Outflow from Pond = Evaporation + Water in Tailings + Seepage = B

Decant Water = C

Year	Impoundment Surface Area (AC)	Seepage Rate Case 1 (gpm)
1	16.0	20
3	35.8	29
7	58.1	31
12	74.5	34



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REVISION	DESCRIPTION	DRAWN	CK'D	DATE		TITLE	SCALE	REV.
					DRWN	WATER BALANCE FIRST YEAR	DRAWING No. FIG. 8.17	△
					CK'D			
					APP			
					APP			
					APP			

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place and might offset to some degree the seepage reduction initially made. On the other hand, severe seepage conditions would minimize the free water pond size making evaporation small and decanting large quantities of liquid difficult.

As shown by the seepage model, we expect to see a zone of seepage surrounding the tailings pond. The size of this zone is controlled by the depth of tailings within the pond. The seepage zone is expected to be 83 feet deep below the lowest elevation of the tailings pond (i.e. 6967 feet). At the maximum surface of the tailings pond, we expect the seepage zone to extend 172 feet outside from the pond in the direction toward the 40° dip at the end of the 12 years of operation. An exception is the area of the dam itself. Thus, the zone of seepage is a pond which is always slightly larger than the tailings pond itself.

8.5 Initial Tailings Liquor Chemistry

The quality of the tailings liquor will be a function of several controlling factors. The first factor is the initial chemical composition of the ore body (feed solids). This, in turn, dictates the chemical composition of the tails solids and the tails liquor. Table 6.1 was prepared by A. H. Ross Associates based upon analysis conducted by Hazen Research Inc. (16).

8.0 SEEPAGE (cont'd)

8.6 Elements of Interest

The items of interest from a water quality standpoint are arsenic, barium, cadmium, copper, cyanide, fluoride, lead, mercury, selenium, silver, thallium and zinc. With the exception of thallium, these elements are listed on the Federal Drinking Water Standards or the State of Utah Water Quality Standards. For the most part, these two standards are the same. The values for these elements present in the tailings liquor are compared with the water quality standards in the Table 8.6.

Cyanide is not listed on the U.S. EPA Drinking Water Standards, but it is listed on Utah Domestic Drinking Water Standards on a case per case determination. It is also listed at 0.005 mg/l for the use by wildlife.

Thallium, though not listed on either set of standards, is a toxic element. It is listed by the U.S. EPA as acutely toxic to fresh water aquatic organisms at 1.4 mg/l.

8.7 Existing Environmental Conditions

The Mercur area has been mined for over 100 years and approximately 6.3 million tons of ore have been mined. This ore has been processed by roasting, retorting, and cyanidation which dispensed fumes, fines, and fluids, over wide areas of the district. Of particular interest are several large tailings piles which have been left behind by these previous mining operations.

TABLE 8.6

U.S. EPA DRINKING WATER STANDARDS
AND
UTAH DOMESTIC WATER QUALITY STANDARDS
(Mg/1)

Element	Standard	Tailings Liquor
Arsenic	0.05	3.04
Barium	1.0	1.4
Cadmium	0.01	0.018
Copper	1.0	3.4
Fluoride	1.4 to 2.4	2.0
Lead	0.05	0.15
Mercury	0.002	0.02
Selenium	0.01	0.002
Silver	0.05	0.03
Zinc	5.0	11.7
Cyanide (Free)		98.2
Thallium		0.14

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The Mercur Canyon has been mined for copper, gold, lead, mercury, nickel, silver and zinc since the mid-1800's. During the period from 1872 - 1895, there were five mills using variations of the cyanide process operating in the area. A second era of development occurred in 1934 - 1937 when two additional mills were constructed. They operated into the World War II era. Thus, during this seven decade period, a total of seven mills have operated in the Mercur Canyon area. These mills have left a legacy behind: large piles of tailings. It is known that some of these tailings have have also been dispersed down the Mercur Creek Watershed toward and into Rush Valley. These tailings piles will contain varying amounts of all of the elements listed in Table 8.6. In addition, they contain small amounts of gold which can be extracted by more modern technology.

8.8 Cyanide Degradation

The cyanide process has been in common use for the separation of a variety of metals from their ores since the turn of the century on a world-wide basis. To put the amount of cyanide use in the mineral extraction industry in perspective, it is useful to know that there were over eight tons per day of cyanide by the mining industry used in Canada alone during 1978 (15). The world-wide use of this compound over the years must lead to the conclusion that a number of

8.0 SEEPAGE (cont'd)

natural degradation processes must be in place. Several studies on the fate of cyanide in the aquatic environment have documented that cyanide is not persistent. This natural degradation in receiving waters is generally attributed to a combination of physical, chemical and biological mechanisms including volatilization, oxidation, biodegradation, photodecomposition and conversion to thiocyanate (2). The relative magnitude of each mechanism appears to be governed by aquatic system variables such as pH, temperature, lake or stream morphology, and water chemistry (24). They reported studies being conducted by the Wastewater Technology Centre of Environment Canada in cooperation with the Dome Mine which is 1.5 miles southwest of the town of South Porcupine, Ontario. This gold and silver mine has been in almost continuous operation since 1912. The Dome Mine employs the process of cyanidation and amalgamation to recover the gold. About one-half of the product is recovered by each process. The mill has a capacity of 2,000 tons per day. The average removal of cyanide by natural processes in the tailings pond was 46% under normal operation. They are experimenting with system modifications which obtain even higher removals of cyanide. The environmental conditions at Mercur, Utah should obtain even better removals of cyanide.

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Renn (22) studied the disappearance of cyanide in anaerobic soil systems. He observed from innoculated soil column tests a significant reduction of CN in the column effluent in 24 hours and a 98% reduction after 20 days provided that the CN is less than 10 mg/l and the pH is 10.

Arsenic compounds can also be converted in soils and sedimentary environments to produce volatile arsenic compounds. Arsenite can be oxidized to arsenate.

8.8.1 Cyanide Waste Degradation

Soluble cyanide degradation generally follows a path whereby the cyanide ion undergoes hydrolysis to form hydrocyanic acid (HCN) which evolves to the atmosphere or by oxidation of simple soluble cyanides to cyanate (CNO). Because soluble cyanide exhibits an ability to form complexes with many metals, the hydrolysis and oxidation reactions usually involve equilibrium states of many metal-cyanide complexes in the same solution. Each of the metal complexes will be stable at certain free metal and cyanide concentrations. As the cyanide concentration increases progressively more complex and stable compounds form.

When cyanide concentrations are considered, one must differentiate between free cyanide (CN or HCN), metal cyanide complexes, [metal(CN)], cyanate (CNO), and thiocyanate (CNS). Total cyanide (CN_T) concentration includes all all of the above. Of greatest concern environmentally is free cyanide because of its toxicity. The other metal cyanide complexes are relatively non-toxic due to the strong bonding of the cyanide radical. Depending upon their relative stability, the metal cyanide complexes may dissociate to liberate free cyanide. The cyanates and thiocyanide compounds are stable in the environment and non-toxic. Therefore, the general goal of cyanide degradation is not the destruction of cyanide but its conversion to stable and less toxic forms.

Common metal cyanide complexes and compounds are listed in Table 8.7 which shows their relative stability. The weaker complexes readily dissociate as the free cyanide concentration decreases and all of the complexes other than $Fe(CN)_6$ are amenable to oxidation. The ferricyanides are extremely stable compounds. The stabilities of cyanide complexes are shown in Tables 8.8 and 8.9.

Factors affecting selection of a cyanide degradation process include technical suitability, waste stream composition, environmental impacts, safety and cost. Various chemical processes are available for waste stream treatment and are discussed below.

TABLE NO. 8.7

COMMON METAL CYANIDE COMPLEXES AND COMPOUNDS

1)	Free CN	CN, HCN
2)	Readily Soluble	NaCN, KCN, $Ca(CN)_2$, $Hg(CN)_2$
3)	Relatively Insoluble	$ZN(CN)_2$, $Cd(CN)_2$, CuCN, AgCN
4)	Weak Complexes	$[Zn(CN)_4]^{-2}$, $[Cd(CN)_3]^{-1}$, $[Cd(CN)_4]^{-2}$
5)	Moderately Strong Complexes	$[Cu(CN)_2]^{-1}$, $[Cu(CN)_3]^{-1}$, $[Ni(CN)_4]^{-2}$, $[Ag(CN)_2]^{-1}$
6)	Strong Complexes	$[Fe(CN)_6]^{-4}$, $[Co(CN)_6]^{-4}$

TABLE NO. 8.8

SOME METAL-CYANIDES COMPLEX IONS IN
ORDER OF DECREASING STABILITY IN WATER (4)

Name*	Formula	Constant
Hexacyanoferrate (III) or Ferricyanide	$[Fe(CN)6]^{-3}$	1 x 10 -52
Hexacyanoferrate (II) or Ferrocyanide	$[Fe(CN)6]^{-4}$	1 x 10 -47
Tetracyanomercurate (II)	$[Hg(CN)4]^{-2}$	4 x 10 -42
Tricyanocuprate (I)	$[CU(CN)3]^{-2}$	5 x 10 -28
Tetracyanonickelate (II)	$[Ni(CN)4]^{-2}$	1 x 10 -22
Dicyanosilverate (I)	$[Ag(CN)2]^{-}$	1 x 10 -21
Tetracyanocadminate (II)	$[Cd(CN)4]^{-2}$	1.4 x 10 -17
Tetracyanozincate (II)	$[Zn(CN)4]^{-2}$	1.3 x 10 -17

*The Roman numerals indicate the oxidation state of the central metal atom.

TABLE NO. 8.9

FREE CYANIDE CONCENTRATION RELEASED AT VARIOUS
LEVELS OF TOTAL CYANIDE, pH = 7 and 25 deg.C (4)

Complex	Concentration (mg/l) Total Cyanide and Respective Free Cyanide Concentrations (mg/l)				
	1 mg/l	10 mg/l	100 mg/l	1,000 mg/l	100,000 mg/l
$[Hg(CN)_4]^{-2}$	0.00002	0.00003	0.000045	0.00007	0.00018
$[Ag(CN)_2]^{-}$	0.00009	0.0002	0.0004	0.0009	0.0041
$[Cu(CN)_3]^{-2}$	0.0003	0.00054	0.00097	0.0017	0.0054
$[Fe(CN)_6]^{-3}$	0.0002	0.0032	0.0004	0.0006	0.0012
$[Fe(CN)_6]^{-4}$	0.0012	0.0016	0.0022	0.0031	0.0061
$[Ni(CN)_4]^{-2}$	0.135	0.215	0.340	0.539	1.324
$[Cd(CN)_4]^{-2}$	*	2.30	3.64	5.77	14.49
$[Zn(CN)_4]^{-2}$	*	2.26	3.59	5.60	14.28

*Calculations indicate that at this dilution the two complexes are essentially completely

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8.8.2 Alkaline Chlorination

This process oxidizes the free cyanide to cyanate with chlorine as the oxidizer as follows:

1) $NaCN + Cl_2 \longrightarrow CNCl + NaCl$

2) $2CNCl + 2Ca(OH)_2 \rightarrow Ca(CNO)_2 + CaCl_2 + 2H_2O$

The first reaction occurs rapidly at pH >10 with the addition of over 3.4 lb of Cl per lb of CN. The Cl can be provided by chlorine gas, hypochlorite, or chlorine solution. The CNCl is a volatile, toxic gas. Its evolution is controlled by maintaining a pH above 10.5 to produce the calcium cyanate.

During the reaction process, the weak metal cyanide complexes dissociate and metal hydroxides precipitate. Farricyanide complex is not decomposed.

This process is widely usd in the chemical process industries and by several gold mining operations for treating clear tailings water. This is an expensive process which consumes 8 to 10 pounds of chlorine per pound of CN, requires very close pH control, and involves the storage and use of large quantities of chlorine a dangerous chemical.

No mills appear to be using chlorination on full scale tailings slurries from carbon absorption plants, probably because they are more dificult to treat. Chlorine consumption in treating slurry is much higher than with clear liquors. For this project, chlorine usage could be as great as 10,000 to 15,000 lbs/day. Chlorine storage areas of at least 200 ton capacity would be required to insure a 30 day reserve supply.

Capital cost for a slurry chlorination plant of the size required could range from $400,000 to $500,000. Operating cost could exceed $700,000 annually.

8.8.3 Ozonation

Ozonation is an exotic water treatment technique now finding increasing application for disinfection and sterilization. Free cyanide, metal cyanide complexes and thiocyanate are effectively destroyed.

This process has not been scaled up commercially to a suitable size for the Mercur tailings stream and would have operating costs somewhat higher than alkaline chlorination. The chief disadvantage is capital cost which would be much higher than alkaline chlorination.

8.8.4 Other Treatments

Various other treatment techniques have been successfully applied to small streams of cyanide bearing solutions. Their disadvantage is the lack of experience in treating large volume tailings slurries. Oxidation processes include hydrogen peroxide reaction and electrochemical oxidation in electrolytic cells both of which have only been extensively tested on clarified solutions. Activated carbon and ion exchange columns have also been tested on clear solutions but would not function on a slurry.

Chemical techniques which tie up free cyanide by reaction with polysulfides create a thiocyanate precipitate which is metastable. To be effective, this must occur under elevated temperature which would require large energy inputs for a tailings stream. Other chemical techniques which convert feee cyanide to ferrocyanide precipitate require large amounts of ferrous sulphate reagent and close pH control and have only been tested with success on clear cyanide solutions, not tailings slurries.

In general, all of the above techniques have proven effective in treating cyanide wastes. However, they have not yet been applied to full-scale tailings slurry discharges and their effectiveness for such an application is not adequately tested. The volume, physical nature and diverse chemistry of a tailings slurry does not appear to make direct treatment of same economically feasible or reliable using present technology.

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8.8.5 Natural Degradation of Cyanide

Previous studies by the Canadian Environmental Protection Service have focused on the natural degradation of free cyanide in the environment. These studies have shown that such processes have high potential for cyanide removal through combinations of physical, chemical and biological mechanisms (24).

8.8.6 Acidification/Volatilization

Free cyanide exists in aqueous solution in equilibrium with hydrocyanic acid (HCN). This equilibrium is extremely pH dependent. Figure 8.18 shows this relationship.

At a pH of 10.3, over 90% of the free cyanide exists as CN^- but at any pH lower than this the relative percentage of volatile HCN increases rapidly. At a pH of 9 over 65% of the free cyanide exists as HCN and at a pH of 8.3, 90% of the cyanide is HCN.

This acidification of tailings is a common phenomon due to absorption of atmospheric CO_2 and production of H_2SO_4 by oxidation of sulfide minerals. Highly buffered tailings such as those from gold mills tend to readily adsorb CO_2 until the concentrations of carbonate and bicarbonate are in equilibrium which is attained at pH 8.3. The Mercur tailings also contain iron sulfides (pyrite) which will tend to decrease the pH when they oxidize.

RELATIVE AMOUNTS OF HYDROCYANIC ACID AND CYANIDE ION
IN SOLUTION AS A FUNCTION OF P_H(4)

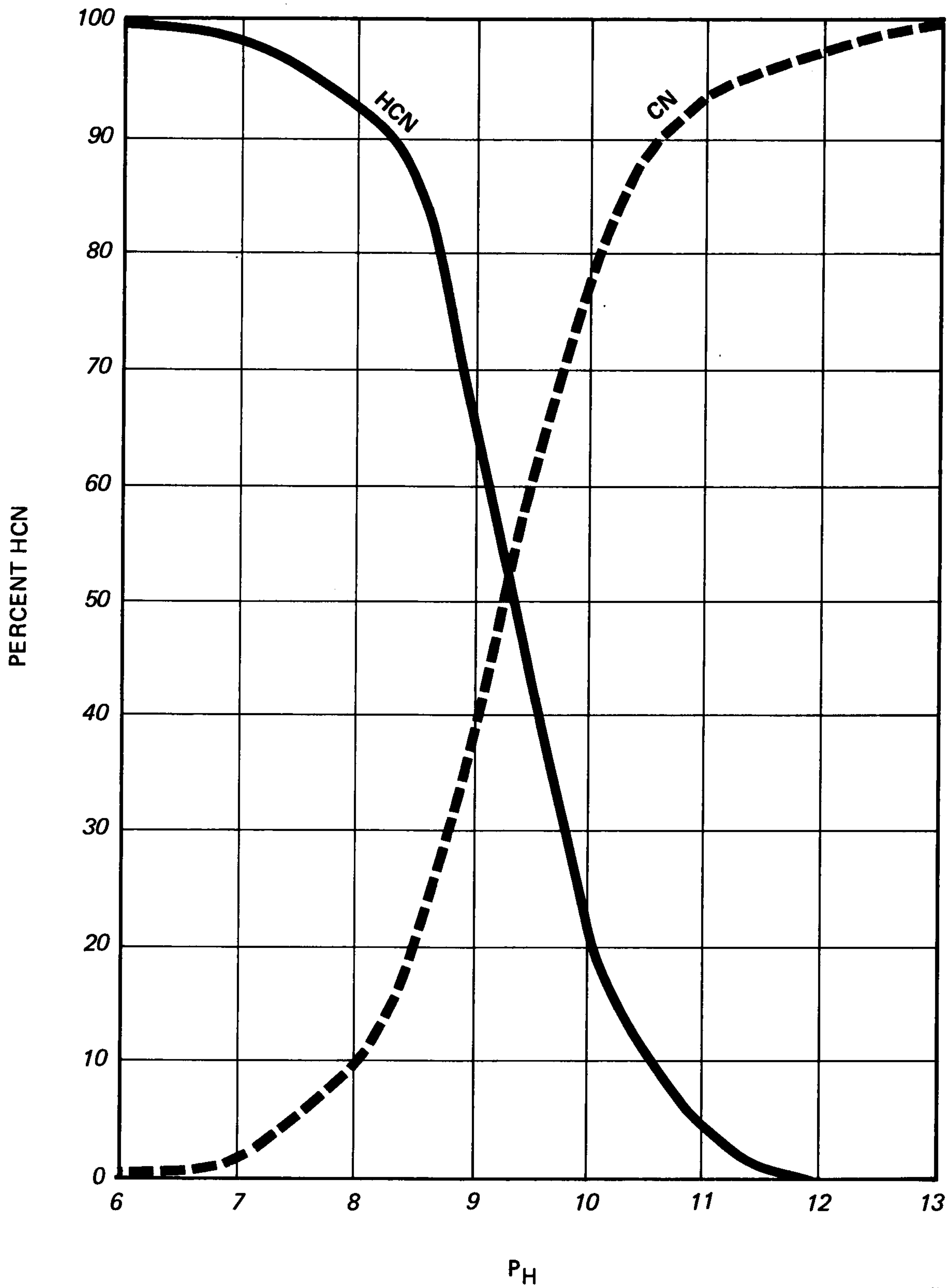

FIGURE 8.18

The HCN has a high vapor presure and readily leaves solution as a gas. As the HCN is evolved, the CN^- concentration drops, placing the metal cyanide complexes in nonequilibrium. The two and four (weak) coordinate complexes rapidly dissociate supplying additional CN^- which, in turn, can be converted to HCN, while the metal ions form hydroxide precipitates. The HCN will dissipate readily with unrestrained ventilation, thus effectively reducing the CN^- concentrations in the liquor.

8.8.7 Oxidation

Natural conversion of cyanide ion to cyanate does occur under aerobic conditions but it is not clear whether this is kinetically significant in a tailings pond situation. Increases in cyanate concentrations at the expense of cyanide have been documented in a barren bleed holding pond at the Dome Mine, Ontario (24).

8.8.8 Biodegradation

Various studies have identified a wide variety of bacteria that degrade cyanide under either aerobic or anaerobic conditions. The biodegradation under aerobic conditions produces cyanate. Under anaerobic conditions, the resultant product is thiocyanate which itself is degraded to ammonia and H_2S. Bacterial counts of cyanide waste water ponds have been shown to increase at the apparent expense of thiocyanate concentrations.

8.8.9 Photodecomposition

Ultraviolet irradiation is known to accelerate the dissociation of strongly complexed metal cyanide compounds. The natural decomposition of iron-cyanide complexes has been observed and half-lives of 20-50 minutes have been calculated. Factors such as turbidity, color, and water depth along with the intensity and angle of incidence of sunlight will affect the rate of photodecomposition.

8.8.10 Conclusion

Gold mill tailings effluents commonly contain cyanide compounds consisting of free cyanide, metal cyanide complexes, cyanates and thiocyanates. The total cyanide concentrations vary with each mill process and range from 75 mg/l to 610 mg/l. The Mercur tailings appear to be in the low range of free cyanide concentration with a high thiocyanate concentration.

Various treatment processes are available to reduce the free cyanide level but they apparently have not been applied to large volume tailings slurries and, therefore, cannot be used at Mercur with reliability if the residual cyanide level must be lower than 10 ppm. A summary of the capabilities of commercial cyanide waste treatment processes is presented in Table 8.10.

TABLE NO. 8.10

ESTIMATED CAPABILITIES OF PROCESSES TO REMOVE CYANIDE/METAL FROM GOLD MILL EFFLUENTS (A), (26)

	Suitable for Removal of Cyanide/Metals of				
Process	CN/HCN	Cd/Zn	Cu/Ni	Fe	CNS(B)
Natural Degradation	yes	partial	partial	no	partial
Hydrogen Peroxide	yes	yes	partial	no	no
Ozonation	yes	yes	yes	no	yes
Acid./Volat.Reneut.	yes	yes	yes	yes	partial
Ion Exchange	yes	yes	yes	yes	possible
Electrochemical Cyanide Recovery	no	Metal - yes cyanide - no(c)		no	no
Cyanide Destruction	yes	yes	yes	no	yes

A. The estimated performance capabilities presented in this Table are based on data from many sources. The final cyanide and metal concentrations attainable and the cost of treatment in any particular case, can only be determined accurately by actual testwork.

B. Not desirable to remove CNS, involves additional reagent.

C. Removal of cyanide is not the goal of this process.

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Review of the natural cyanide degradation research indicates that free cyanide concentrations can be significantly reduced in the Reservation Canyon tailings pond by interaction with the atmosphere, bacteria, and sunlight. It is not feasible to model these effects accurately and quantitative predictions are impossible, but certain actions can be taken to maximize these processes.

Aeration appears to be important in volatilizing HCN and possibly producing cyanate. This will be enhanced at Mercur by maintaining tailings flow over a wide beach. This action will also maximize the effects of sunlight and bacteria on the liquor. Public health hazards from the volatilizing HCN will be minimal due to the slow vaporization rate, the natural ventilating characteristics of the site and by fencing the site to exclude the public. Men working in the tailings pond should not be exposed to concentrations in air greater than 10 ppm (PEL explosure for an 8-hour period).

8.9 Contaminant Migration

Seepage from a tailings pond will leave the confines of the pond basin according to variations of Darcy's Law. The seepage rate can be calculated taking into account the hydraulic properties of the settled tailings, liner (if present), unsaturated earth above the water table, and saturated earth below the water table (18). The seepage will have dissolved constituents at higher concentrations than those in the natural ground water and as such can be considered contaminants. However, these contaminants will not produce a homogenous seepage plane and depending upon proximity to water use and the natural attenuation of certain contaminants, the seepage plane may never adversely affect the use of the ground water. The leading edge of the contaminant zone is identified by increased contaminant concentrations. This last point must be kept in mind because physical and chemical processes will affect the contaminant concentration of various elements and compounds. For example, heavy metals are relatively immobile and tend to be attenuated whereas some anions such as Cl, SO_4, and NO_3 tend to travel further with less attenuation.

The contaminant zone will be effected by dispersion, adsorption, precipitation and dilution (27).

8.9.1 Dispersion

Dispersion causes contaminant concentrations to decline. It is a process whereby the contaminant zone is mixed with uncontaminated water laterally and longitudinally, thus occupying a larger volume.

Because this diluting effect lowers contaminant concentrations, it is viewed as an attenuating process. In a

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stratified and fractured flow media such as exists down dip from the Mercur tailings pond significant dispersion would be caused mainly by bifurcating flow paths and turbulent mixing. Such flow cannot be modeled accurately with advection-dispersion equations (12).

In the Mercur case, the contaminant zone will tend to follow the top of the Manning Canyon formation down dip within the mountainous, bedrock recharge area. Along this flow path, additional ground water will be supplied to the contaminant zone from natural ground water recharge. This effect would tend to dilute the contaminant concentration significantly. The area of potential recharge for dilution is approximable 12 square miles (see Figure 7.1) before reaching the Cedar Valley aquifer.

Just looking at the drainage area above the tailings pond (vertically above the seepage flow path) there are about 707 acres of land that receive about 17.4 in. annual precipitation of which 12% infiltrates into the ground. This recharge amounts to about 123 Acft/yr or 2.6 times greater than the average annual seepage rate (29 gpm = 46.8 Ac ft/yr). Thus the potential dilution of the contaminant concentration that was 100 mg/l could be diluted to 28 mg/l within about a mile from the tailings pond.

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8.9.2 Adsorption

Adsorption is a surface phenomona caused by materials possessing high surface areas per unit volume. Clay minerals generally exhibit this effect because of their electrostatic attraction properties as well as their tremendous area per unit volume. However, organic matter and silts also contribute significant adsorption capacity. The magnitude of surface adsorption can be determined with soil column tests to derive distribution coefficients. This work can then be used to predict the contaminant attenuating potential of the soils through which seepage occurs (11).

The adsorption potential of the soils under the Mercur tailings pond has not been quantitatively determined via column tests. Such tests are difficult to do with complex chemistry present in tailings solutions and their results might not be characteristic of the entire area due to the heterogenous nature of the soils (12).

Soils beneath the Mercur tailings pond have clay size content of 14-32% and silt size content of 22-46%. Cation exchange capacity (a measure of base metal adsorption potential) of the soils varies from about 14 meg/100g (Mili equivalents/100 g dry soil) to 26 meg/100g. Soil pH varies from 7.5 to 8.0. Such soils will have some limited

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adsorption capacity for the cations in the seepage solution such as dissolved metals. Anions such as cyanide,sulphate, cyanate, and chloride are usually not adsorbed; however, some chemically bonded surface complexes may form with the cyanides due to ligand exchange mechanisms.

8.9.3 Precipitation

Precipitation of contaminants can occur due to neutralization of acid by contact with basic minerals and by mixing with alkaline ground water, and by neutralization of alkali in the tailings solution by carbon dioxide in the atmosphere. It can also occur by change of oxidation state. Precipitation can be the most significant attenuation process that effects the base metal concentrations in the tailings water as the pH drops from 10 to the 7-8 range after operations cease.

Work in Canada by John Cherry and others (5) has shown a general correlation between pH and ground water concentrations of heavy metals. In the case of acid seepage, they found that dissolved metals content dropped to less than 1 mg/l when the pH exceeded 7.

Although the Mercur tailings will probably never achieve a pH less than 8.3 due to their buffering capacity, there does appear to be potential for precipitation of heavy metals in the limestone under the tailings. This is apparent from analyses done on drill hole samples obtained from holes drilled through the old Golden Gate tailings pile at Mercur. Results from these analyses are listed in Table 8.11. The Golden Gate tailings are waste from the previous cyanide gold milling of Mercur ores which should be chemically similar to the tailings produced from the proposed mill (with the exception of gold).

Inspection of Table 8.11 shows that there is a pronounced zone of heavy metal concentration in the limestone bedrock within 209-40' of the base of the tailings. This indicates that soluble metals in the seepage were precipitated in this zone. The data also shows the relative attenuation effect of precipitation and adsorption in the soil versus the precipitation effect of the bedrock in drill hole 6T-28.

Although no direct quantitative seepage analyses are possible under the old tailings, a shallow water well (GC-20) immediately adjacent to the old tailings has been sampled and the concentrations of the same elements are listed in Table 8.12. One can see from these data that the heavy metals in the old tailings pile are not contributing heavy metals to the local ground water in significant

TABLE NO. 8.11

GOLDEN GATE TAILINGS DRILL HOLE CHEMISTRY (10)

DRILL HOLE GT-25

Depth (ft)	As (ppm)	Au (ppm)	Zn (ppm)	Tl (ppm)	Hg (ppm)
20-25	3000	1.00	130	160	11.1
60-65	4100	1.08	150	200	10.1
100-105	3900	0.70	195	260	11.1
140-145	2900	0.70	155	160	15.7
Base of tailings at 155 ft			Top of bedrock at 160 ft		
160-165	5400	3.50	108	110	9.6
180-185	2200	0.20	80	57	4.8
200-205	1000	0.15	150	32	5.7

DRILL HOLE GT-28

Depth (ft)	As (ppm)	Au (ppm)	Zn (ppm)	Tl (ppm)	Hg (ppm)
40-45	1900	0.10	175	110	5.5
Base of tailings at 45 ft			Top of soil at 45 ft		
60-65	200	0.10	287	5	0.66
80-85	44	0.10	130	2	0.18
Base of soil at 85 ft			Top of bedrock at 85 ft		
100-105	12000	1.10	112	37	7.5
120-125	1300	0.15	330	40	3.2
140-145	640	0.20	65	7	1.5

TABLE NO. 8.12

SELECTED WATER CHEMISTRY/MERCUR AREA (10)

(all dissolved constituents in ppm)

	Fairfield Spring	Manning Spring	GC-20
As	.001	.001	.001
Ba	.025	.030	.050
Cd	.001	.001	.001
Cl	11.12	15.36	425.80
Cr	.001	.001	.001
Cu	.001	.010	.020
F	.10	.14	.30
Fe	.001	.001	.360
Pb	.001	.001	.002
Hg	.0002	.0002	.0003
Se	.001	.001	.001
Ag	.001	.001	.001
Na	8.80	13.50	195.00
Tl	.001	.001	.002
Zn	.010	.003	2.270
Mn	.001	.001	.060
SO_4	24.0	33.0	1,360.
HCO_3	224.80	236.30	625.86
pH	7.40	7.60	7.00

concentrations. Other water samples obtained from the Manning Canyon Spring and from Fairfield Spring also show the same results (See Table 8.12).

8.9.4 Summary of Attenuation Effects

Site specific investigations of the local conditions have indicated that the attenuation processes of dispersion, dilution, adsorption, and precipitation can significantly reduce contaminant levels in seepage from the proposed tailings pond. Quantitative estimates of contaminant concentrations in the seepage zone are not feasible due to the nature of the geology which prevents accurate modelling of the seepage configuration. However, experience at other mining operations and examination of the old Mercur tailings indicates that the heavy metal concentrations will be strongly attenuated to very low concentrations within a short distance from the tailings bedrock interface (Table 8.11). Common ions such as sulfate, sodium, and chloride will not be as highly affected by geochemical processes of attenuation but will be attenuated by dispersion and dilution. These ions, however, pose no health problem.

Attenuation of cyanide compounds will be largely due to dispersion and dilution with some adsorption possible. These compounds will also tend to break down to HCN due to the ground water pH of 6-8. This gas will largely be left behind in the partially saturated seepage zone. Where the HCN partial pressure is low it may remain dissolved and be carried by the ground water.

Also many studies have shown that biodegradation of low concentrations of cyanide is a common mechanism in both water and soils and is an effective means of significantly reducing cyanide levels under both aerobic and anaerobic conditions within the tailings impoundment.

8.10 Summary of Impacts

The nearest productive well is approximately four and one-quarter miles to the east-southeast of the tailings pond. It is registered in the name of Wofford. The well is used for domestic, irrigation and stock watering purposes. The water depth is at 487 feet at an elevation of 4,863 ft, since the surface elevation is 5,350 ft. The balance of the productive wells of interest are seven miles or further from the tailings pond.

The nearest productive spring is located in Manning Canyon some 2-1/2 miles from the mill. This spring and those in Fairfield may be downgradient. Seepage from the tailings pond is not expected to reach the mountain aquifer within the operational life of the tailings facility. When it does reach the aquifer it will move down-gradient towards the above mentioned discharge points. By the time this seepage has reached these dicharge points the containment concentration levels are expected to be so low that they should be unmeasurable. This is because the volume of the potentially contaiminated seepage is so small when compared to the volume of recharge to this aquifer. The beneficial uses of these water sources should not be impacted. See Figure 7.1.

8.11 Mitigation Measures

In the original construction of the tailings dam and pond the Manning Canyon shale is exposed and used for construction of the core of the dam. Having this shale exposed in the area of the first stage of development of the tailings dam makes it available to aid in the initial construction phase of the tailings pond. During this first stage of the tailings pond construction the shale on the bottom will be compacted, thus, providing an area of control even before it is overlayed with tailings.

Manning Canyon shale is available in the tailings dam and pond area. This shale will be available for liner material if areas of suspected permeability are encountered during pond construction. This shale is also available above the high water mark of the impoundment at all times and could be used for liner material during pond operation if needed.

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8.12 Monitoring Wells

In order to discover any unexpected excursion of containmant from the impoundment, a ground water monitoring system will be installed. This system will be composed of two monitoring wells, one drilled to the bottom of the Oquirrh Formation (limestone) and the other to the limestone interbed of the Manning Canyon shale. These wells will be drilled and completed with casing which is slotted at the bottom and cemented or sealed with clay above the slotted interval. On a monthly basis, conductivity and water level will be measured. Water samples will be collected for complete chemical analysis on a quarterly basis and more often if conductivity changes indicate a major change of total dissolved solids. Complete chemical analysis as proposed will not include organics analysis but will include cyanide analysis.

These wells will be located to the east (MW 1) and southeast (MW 2) of the impoundment where they would most likely encounter seepage moving down-dip in the rock strata. they will be drilled and operational prior to mill startup in mid 1983. See Figure 1.4.

Monitoring wells to the west of the main dam are not proposed because seepage past the clay core of the dam will tend to move down-dip generally to the east or vertically.

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It is very unlikely that a well to the west of the dam would ever collect seepage even if drilled to the top of the Long Trail shale. The nearest points of ground water discharge will also be sampled monthly to establish a good quality baseline.

8.13 Reclamation

The tailings pond and dam will be reclaimed according to the regulations and procedures established by the Division of Oil, Gas, and Mining of the Department of Natural Resources. During the various construction stages of the tailings pond and dam, the topsoil will be removed and stockpiled for use during the reclamation phase of the project. A period of stabilization will be necessary before the topsoil can be replaced and revegetation can proceed.

Another consideration is to insure that the toxic heavy metals will remain in the tailings solids and not be released to seepage after the pond is shut down. Mr. Peter Mason of A. H. Ross & Associates has conducted calculations that show 3.5% sulfur is equivalent of 214 acid/ton if oxidized. This amount of acid would neutralize tailing liquor to pH 7.7. Ore contains large amounts of calcite ($CaCO_3$ - ore has 14.4% CO_3^{-2}). Tailings appear to buffer at pH 7.7 with additional acid. Thus, there is

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sufficient buffering capacity to ensure that the heavy metals will stay in the tailings solids after the pond is shut down (17).

9.0 CONCLUSIONS

Analysis of pertainent geological and hydrological aspects of this proposed tailings facility indicate that there will be seepage from the impoundment. Under the constraints imposed on this seepage by the geology of the site and the operation of the tailings distribution system, the average total seepage rate is calculated by Davy McKee to be 29 gpm.

The only way to reduce this seepage further would be to seal the pond with an actificial or clay liner. The steep slopes and irregular surface of the impoundment area preclude satisfactory installation and maintenance of artifical liners. A clay liner developed from upgraded local clays could possibly be installed only with great difficulty but seepage calculations for this case indicate a reduction in average total seepage rate of only 13% over the case with no liner (7).

Because the expected attenuation and natural degradation processes will nullify the impacts of the seepage upon the ground water use, additional seepage reduction beyond that calculated for the proposed tailings management is not warranted. The applicant proposes that the impoundment construction and operation as described in this document is the best available technology to prevent pollution of the water of the State.

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